Natural Propagation and Habitat Improvement, Volume I Supplement A

Oregon: Evaluation of Fisheries Enhancement Projects on Fish Creek and Wash Creek

Annual Report
1982 - 1983

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Bonneville Power Administration
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NATURAL PROPAGATION AND HABITAT IMPROVEMENT

VOLUME I - OREGON

SUPPLEMENT A: HABITAT ENHANCEMENT EVALUATION OF FISH AND WASH CREEKS

ANNUAL REPORT, 1983

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EVALUATION OF FISHERIES ENHANCEMENT PROJECTS ON FISH CREEK AND WASH CREEK, 1982 and 1983

Fred H. Everest and James R. Sedell

Pacific Northwest Forest and Range Experiment Station

Forestry Sciences Laboratory

3200 Jefferson Way

Corvallis, Oregon 97331

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Evaluation of Fisheries Enhancement Projects on Fish Creek and Wash Creek, 1982 and 1983

EXECUTIVE SUMMARY

The Anadromous Fish Habitat Research Project (RWU-1705) of the Pacific Northwest Forest and Range Experiment Station entered into an agreement with the Mt. Hood National Forest, Estacada Ranger District in 1981, and Bonneville Power Administration in 1982 to evaluate habitat improvements for anadromous salmonids on Fish Creek in the upper Clackamas Basin. The enhancement projects have been funded by both BPA and Knutson-Vandenberg funds from timber sales on the Estacada Ranger District. Project construction is under the direction of the Estacada Ranger District.

The primary objectives of the evaluation effort include:

1) Evaluate and quantify the changes in salmonid spawning and rearing habitat resulting from a variety of habitat improvements.

2) Evaluate and quantify the changes in fish populations and biomass resulting from habitat improvements.

3) Evaluate the cost-effectiveness of habitat improvements developed with BPA and KV funds on Fish Creek.

'his report integrates data for the evaluation efforts collected in the Fisn Creek Basin in 1982 and 1983. Pertinent data from other agencies are also included.

Fish Creek Physical Habitat and Salmonid Populations

Channel processes and landforms have created and maintained four basic habitat types in Fish Creek. These include riffles, pooh, side channels and alcoves. Beaver ponds are a fifth specialized type of habitat. Riffle habitat acounts for more than 80 percent of the total habitat surface area in Fish Creek. Pools make up less than 10 percent. The pool to riffle ratio is a low 1:14. Side channels make up about 9 percent, quiet alcoves about 1 percent and a beaver pond on an old channel about 0.3 percent. Quiet water habitats are scarce in Fish Creek.

Salmonid Densities and Biomass

Steelhead trout were the most abundant salmonid in the basin in 1982 and 1983. Fish Creek is an excellent stream for rearing juvenile steelhead since they prefer fast water habitats.

Steelhead trout juveniles account for more than 90 percent of the biomass of salmonids in the basin. Young-of-the-year steelhead (0+) were the most abundant fish numerically. Even though yearling steelhead made up less than one-third of the total salmonids, their biomass accounted for more than one-half the total salmonids. Coho salmon were a minor component of the rearing salmonids in Fish Creek. Coho represent about 2 percent of the total salmonid numbers and only about 1 percent of the biomass. The amounts of each habitat type and the numbers of each species using each habitat type are summarized for 1982 and 1983 in Tables i and ii.

Table i. --Area and volume of rearing habitat types in Fish Creek used by anadromous fish and thelr associated salmonid densities and biomass.

FISH CREEK 1982

SPECIES	HABI TAT	AREA IN SYSTEM (m^2)	VOLUME IN SYSTEM (m^3)	NUMBER FISH ESTIMATE BY HABITAT	BIOMASS(g) FISH ESTIMATE BY HABITAT	#/m^2	g/m^2	#/m^3	g/m^3
COHO	Alcove	949	264	305	1,885	0.30	2.00	1.20	7.10
	Riffle	78,300	21,675	1,951	6,341	0.02	0.10	0.10	0.30
	Sidechannel	11,864	2,643	2,115	14,640	0.20	1.20	0.80	5.50
	Pool	3,796	1,850	131	1,286	0.03	0.30	0.10	0.70
	Beaver Pond	192	36	264	1,223	1.40	6.40	7.30	34.0
Total		95,101	26,468	4,766	20,565				
0+STHD	Alcove	3,379	814	1,808	4,119	0.50	1.20	2.20	5.10
	Riffle	282,147	66,716	146,952	432,927	0.50	1.50	2.20	6.50
	Sidechannel	30,411	7,441	32,867	82,934	1.10	2.70	13.50	34.00
	Pool	21,964	11,390	8,082	21,807	0.40	1.00	0.70	1.90
	Beaver Pond	192	36	1	8	0.01	0.04	0.03	0.20
Total		338,093	81,397	189,710	541,795				
1+STHD	Alcove	3,379	814	154	2,875	0.10	0.90	0.20	3.50
	Riffle	282,147	66,716	41,894	769,949	0.20	2.70	0.60	11.50
	Sidechannel	30,411	2,441	4,087	74,556	0.10	2.50	1.70	30.50
	Pool	21,964	11,390	4,028	89,088	0.20	4.10	0.40	7.80
	Beaver Pond		36	4	40	0.02	0.70	0.10	1.10
	Total	330,033	91,397	50,162	936,508				

Table ii. Area and volume of rearing habitat types in Fish Creek used by anadromous fish and their associated salmonid densities and biomass. September, 1983.

SPECIES	TAT	AREA IN SYSTEM (m^2)	VOLUME IN SYSTEM (m^3)	ESTIMATE FISH NUMBER BY HABITAT	ESTIMATE FISH BIOMASS BY HABITAT	#/m^2	g/m^2	#/m^3	g/m^3
Coho	Alcove	1,272	327	433	2,120	0.30	1.90	1.30	6.50
	Riffle	83,780	29,044	3,490	19,395	0.04	0.20	0.10	0.70
	Side channel	15,044	4,229	0,867	25,704	0.60	1.70	2.10	6.10
	Pool	4,214	2,017	2,2B4	10,510	0.50	2.50	1.10	5.20
	Beaver pond	296	124	241	675	0.80	2.30	1.90	5.40
	Total	104,606	35,741	15,315	58,404				
Chlnook	Alcove	1,272	327	9	27	0.01	0.02	0.03	0.08
	Riffle	83,780	29,044	388	1,551	0.005	0.02	0.01	0.05
	Side channel	15,044	4,229	0	0	0	0	0	0
	Pool	4,214	2,017	821	4,470	0.19	1.06	0.41	2.22
	Beaver pond	296	124	0	0	0	0	0	0
	Total	104,606	35,741	1,218	6,848				
0+ STHD	Alcove	4,527	1,009	1,015	2,841	0.20	0.60	1.00	2.80
	Riffle	301,897	89,399	99,115	277,522	0.30	0.90	1.10	3.10
	Side channel	38,622	3,906	22,210	70,752	0.60	1.80	5.70	18.10
	Pool	24,380	12,415	9,340	30,823	0.40	1.30	0.80	2.50
	Beaver pond	296	124	4	13	0.01	--	0.03	--
	Total	369,772	106,853	131,584	381,951				
1+ STHD	Alcove	4,577	1,009	165	4,340	0.04	1.00	0.20	4.30
	Riffle	301,897	89,399	43,670	785,077	0.10	2.60	0.50	8.80
	Side channel	38,622	3,906	3,396	57,732	0.10	1.50	0.90	14.80
	Pool	74,300	12,415	5,475	91,432	0.20	3.80	0.40	7.40
	Beaver pond	296	124	0	0	0	D	0	0
	Total	369,777	106,853	57,706	938,581				

Effects of Habitat Improvements on Spawning Habitat

A primary need of any habitat enhancement program is identification of factors limiting fish production. The objective of initial enhancement efforts on Fish Creek was to increase spawning area for steelhead. A series of 5 rock berms constructed in 1981 to catch gravels on upper Fish Creek were successful and 35 m^2 of good spawning area was added to the system. Steelhead are utilizing these gravels. But, the balance between steelhead spawning and rearing area in Fish Creek appears to be near optimum at the present time and additional steelhead spawning gravels are probably not needed. Coho spawning gravels are also adequate, but lack of suitable gravels might be limiting chinook production in the Fish Creek system.

Twenty-one boulder berms constructed on Fish Creek and Wash Creek in 1983 made significant changes in the overall habitat structure of the stream. The berms were designed primarily to enhance spawning habitat for chinook. Each berm that spanned the stream functioned as a low dam that initially created pool habitat. A total of 18 berms created pool habitat totaling 5,763 m^2 and 2,644 m^3 (Table iii). Average depth of pools at low flow was 0.43 m. Construction of the berms increased pool habitat for the entire anadromous fish reach of Fish Creek by about 24 percent and reduced total riffle habitat by about 2 percent (Table iv). The increased pool area and volume created by the berms will slowly develop into spawning habitat for chinook as the pools fill with bedload gravels.

Berm construction also created significant changes in substrate composition. The area of streambed within the wetted perimeter around each berm site was dearmored of boulders and rubble during construction. The large

Table iii. Changes in riffle and pool habitat resulting from construction of rock berms on Fish Creek and Wash Creek, 1983.

Site	Number Berms	Average pool depth (m)	Total pool area increase (m2)	Pool volume increase (m3)	Volume increase per pool(mi
1) Wash	3	.38	385	146	49
2) Suspender reach (a)	7	.58	2,366	1,372	196
3) Suspender reach(b)	8	.38	3,012	1,126	281
4) Bridge	3	0	0	0	--
Totals	21		5,763	2,644	

Table iv. Habitat area and volume in stream channels accessible to anadromous fish before and after construction of 21 rock berms on Fish Creek and Wash Creek, 1983.

	Before		After		% Change	
Habitat type	Area m^2	Volume m^3	Area m2	Volume m3	Area	Volume
Riffle	30 1,897	89,399	296,134	87,692	-2	2
Pool	24,280	12,415	30,143	15,059	+24	+21

particles were used to build the berms, and after completion of the berms underlying gravel was exposed (Table v). Gravel substrate increased a total of 1,381 m^2 within the wetted perimenter, but there was no immediate increase in spawning area. The exposed gravels were primarily in the bottom of pools where depth and velocity characteristics would preclude spawning.

Effects of Habitat Improvements on Rearing Habitat.

A small beaver pond on a side channel of Fish Creek at km 3 is the most productive habitat (per area and volume) for juvenile coho salmon in the Fish Creek system. An off-channel pond, developed in 1983 as a coho rearing area, drains into the beaver pond and shares many of its productive characteristics. The off-channel pond historically contained water in winter and spring but was dry in summer and fall. The pond was used heavily by beavers during the wet season. Periodic beaver use, coupled with an abundance of large and small organic debris from beaver activity and salvage logging provide the pond with a rich supply of nutrients. The developed off-channel pond with its perennial water source more closely resembles a beaver pond than any other habitat type in Fish Creek basin and should be as productive for coho rearing.

The developed off-channel pond has added 4,600 m^2 of "beaver pond" habitat to lower Fish Creek, a 15 fold increase over natural levels. The increase in volume of 3,600m^3 is even greater--a 29 fold increase. If the pond produces coho at the same rate as the natural beaver pond, about 7,200 juvenile coho could be accomodated in summer and a smolt output of

Table v. Changes in quantity of streambed gravels resulting from construction of boulder berms on Fish Creek and Wash Creek, 1983. No increase in spawnable gravels was noted.

Site	Number Berms	Substrate area affected (m^2)	Total increase in gravel (m^2)	Gravel increase per berm (m^2)
1) Wash	3	259	115	38
2) Suspender reach (a)	7	744	342	49
3) Suspender reach (b)	8	2,250	817	102
4) Bridge	3	357	107	36
Totals	21	3,610	1,381	x = 56

about 5,760 fish might be expected. Based on observations of wild coho abundance in 1982 and 1983, the pond might increase smolt output from Fish Creek by 60 to 190 percent.

Spawning habitat in the pond's two inlets should eventually be sufficient to naturally seed the pond with coho fry. A minimum of 20 adult female coho can be accomodated on spawning areas in the inlets if some additional spawning area enhancement is done in the south inlet. Twenty females should produce about 60,000 eggs, 18,000 fry, or 4,000+ smolts--enough to utilize much of the available habitat in the pond.

For the first 3-4 years of operation an effort will be made to seed the pond artifically by collecting coho fry from Fish Creek and transporting them to the pond. Coho that begin their smolt migration from the pond should home back to pond inlet streams as adults. Once this pattern is estabiished the pond should be seeded naturally each year.

When development of the pond was completed in the fall of 1983, 150 juvenile coho were captured by electrofishing in Fish Creek and introduced to the pond. The fish averaged 77.4 mm in length and 5.2 g in weight. The first out migrant smolt (727 mm and 23.0 g left the pond on March 14, 7984. The survival and growth rates of these fish will continue to be monitored as they leave the pond in the spring of 1984.

Benefit/Cost Analysis

Since most habitat improvements on Fish Creek were constructed in 1983, no benefit/cost analyses have been completed to date. At least one additional year of evaluation, and in some cases several more years, will

be required before accurate benefit/cost ratios can be calculated for specific projects.

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INTRODUCTION

The Anadromous Fish Habitat Research Unit of the Pacific Northwest Forest and Range Experiment Station entered into an agreement with the Mt. Hood National Forest, Estacada Ranger District in 1982 to conduct biological and economic evaluations of fish habitat improvement structures installed by the District in Fish Creek, a tributary of the upper Slackamas River. The planned habitat improvements and the evaluation were financed by Knutson-Vandenberg (K-V) funds from the Suspender Timber Sale on Fish Creek. A five year evaluation (1982-1986) was planned. Factors limiting production of anadromous salmonids in the basin were identified during the first year and as a result additional habitat enhancement projects were planned.

The enhancement and evaluation projects on Fish Creek were expanded in 1983. The increased effort for both enhancement and evaluation is funded and administered by the Bonneville Power Administration (BPA).

The primary objectives of the expanded evaluation efforts include:

1) Evaluate and quantify the changes in salmonid spawning and rearing habitat resulting from a variety of habitat improvements.

2) Evaluate and quantify the changes in fish populations and biomass resulting from habitat improvements.

3) Evaluate the cost-effectiveness of habitat improvements developed with BPA and KV funds on Fish Creek.

This annual progress report will integrate data for the evaluation efforts collected in the Fish Creek basin in 1982 and 1983. Pertinent data from other agencies are also included.

DESCRIPTION OF STUDY AREA

The Fish Creek basin lies in north, central Oregon on the west slope of the Cascade Range and drains into the upper Clackamas River (Fig. 1). The watershed is 21 km long, averages approximately 10 km in width, and covers 106 km^2. The terrain is steep and mountainous with bluffs in the lower canyons typical of the Columbia River Basalt formation. The valley bottoms are typically narrow with incised stream channels and narrow floodplains.

Fish Creek heads near the summit of the Cascade Mountains at an elevation of about 1,400 m and flows generally north for about 21 km to its confluence with the Clackamas River about 14 km east of North Fork Reservoir. The channel gradient is steep throughout this distance, generally exceeding 5 percent except for the lower 6 km where gradients average 2 percent. The steep gradient and volcanic geology create a stream with predominately riffle environment and boulder substrate. The mainstern of Fish Creek is 5th order as defined by Strahler (1957) and the annual flow variation near the mouth ranges from 0.5 m^3/sec in late summer to more than 100 m^3/sec during winter freshets.

One major tributary, Wash Creek, a 4th order system, heads in the southwest portion of the Fish Creek basin and enters Fish Creek at km 11. The Wash Creek subbasin covers 25 km^2 and has a mainstem length of 8 km. The stream heads at an elevation of about 1,200 m. The mainstem habitat of Wash Creek is steep bouldery riffle in a narrow incised channel. Average minimum Sumner flow is approximately 0.3 m^3/sec.

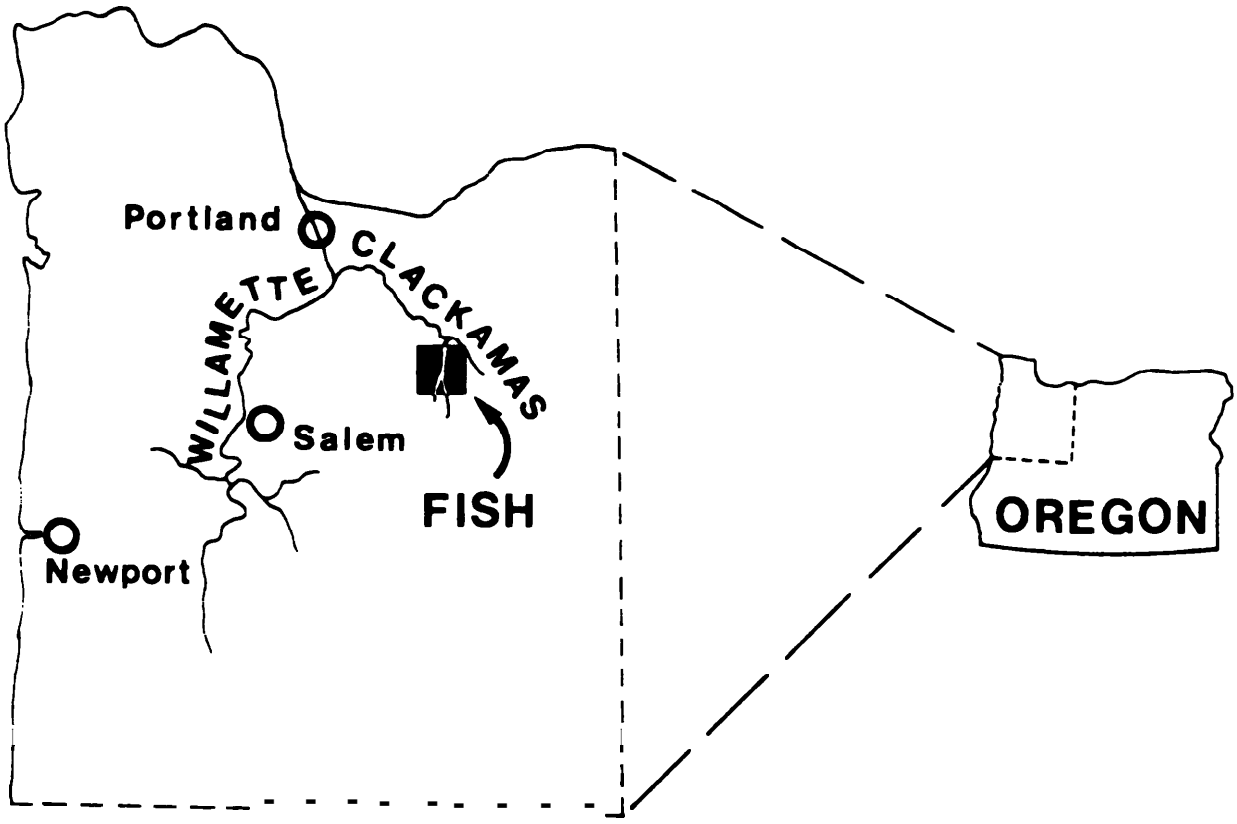


Figure I.--Location of Fish Creek in northwest Oregon.

The Fish Creek basin supports a significant population of anadromous salmonids, including summer and winter steelhead, spring chinook salmon, and coho salmon. Upper areas of the basin contain resident rainbow trout. Few resident salmonids are found within the range of anadromous fish and all rainbow sampled there were treated as steelhead. Approximately 18 km of habitat are used by anadromous salmonids, including the lower 5.5 km of Wash Creek. The upper reaches of both Fish and Wash creeks are blocked to anadromous salmonids by major waterfalls. Water temperatures in habitat used by anadromous fish are generally favorable for fish production, ranging from near 0^{o} C at times in winter to about 20^{o} C in most summers. In years with low summer streamflow and high summer temperatures, however, water temperatures reach stressful levels for salmonids. For example, in early September 1980, temperatures in lower Fish Creek reached 24^{o} C for several consecutive days.

DESCRIPTION OF HABITAT IMPROVEMENTS

Two types of habitat improvements were completed on Fish and Wash Creeks in the summer of 1983. Twenty-one boulder berms were constructed, 3 on Wash Creek and 18 at three locations on Fish Creek (Fig. 2), to enhance both spawning and rearing opportunities for steelhead trout, and spawning for chinook salmon. Also, a major rearing habitat improvement for juvenile coho salmon was constructed at km 2.5 on Fish Creek. The project involved establishment of an off-channel rearing pond on an ancient flood terrace adjacent to Fish Creek.

Boulder Berms

Boulder berms were constructed with heavy equipment by removing the boulder armor layer from the streambed at specific locations and stacking the boulders in a v-shaped curve oriented downstream. Finished berms ranged from 1 to 1.5 m in height and up to 30 meters long. All but 3 of the berms extended from bank to bank across the stream. Al? of the berms that spanned the width of the channel created large dammed pools upstream which will serve as rearing habitat for salmonids and settling basins for bed load gravels moving downstream during high flows. Impounded gravels will eventually serve as spawning areas for adult salmonids.

Off-channel Rearing Pond

The off-channel rearing pond was established by building a gravity-feed pipeline from Fish Creek to an ancient flood terrace about 200 m below the pipeline intake (Fig. 3). The 25 cm diameter pipe is

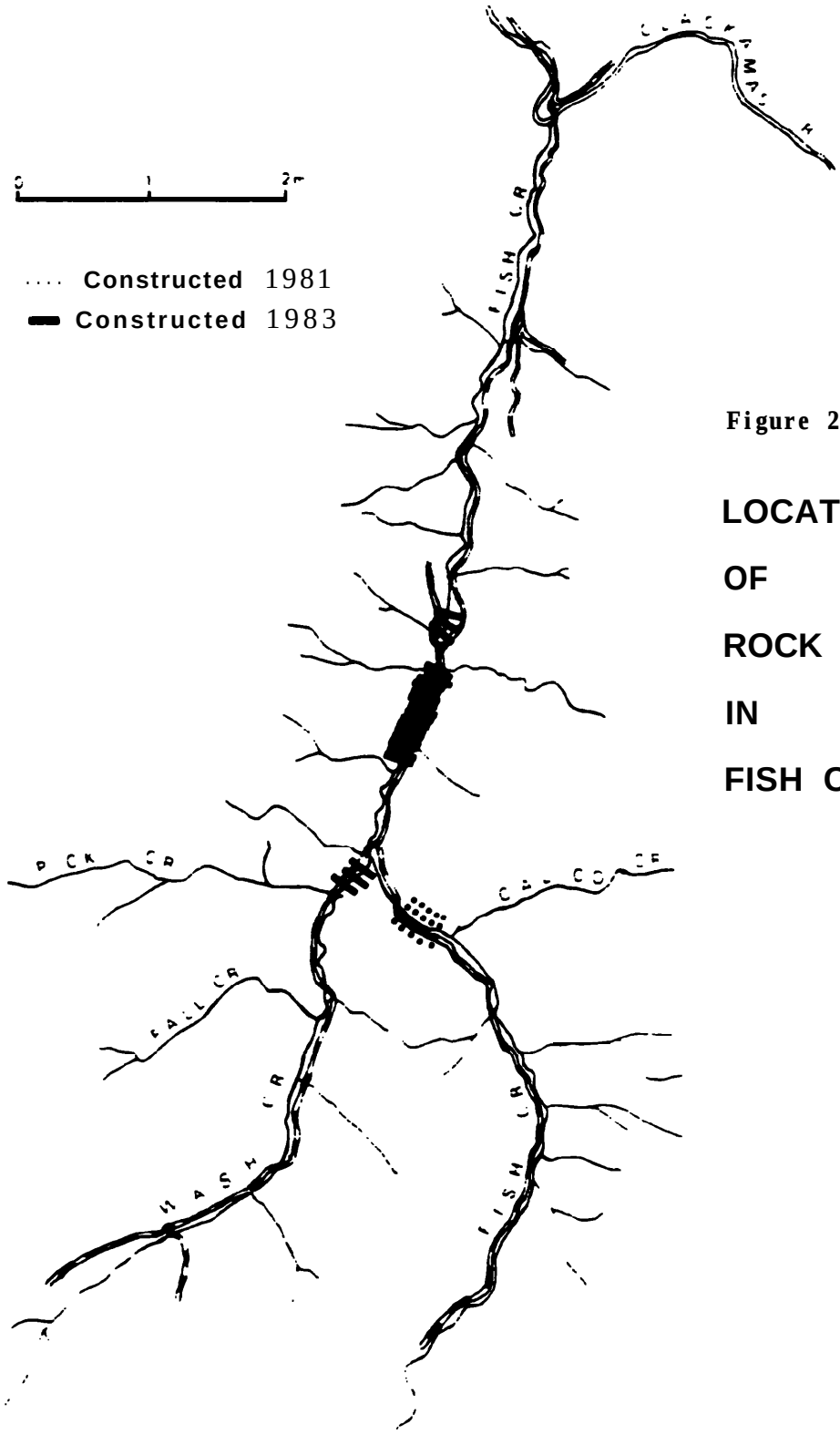


Figure 2

LOCATION OF ROCK BERMS IN FISH CREEK

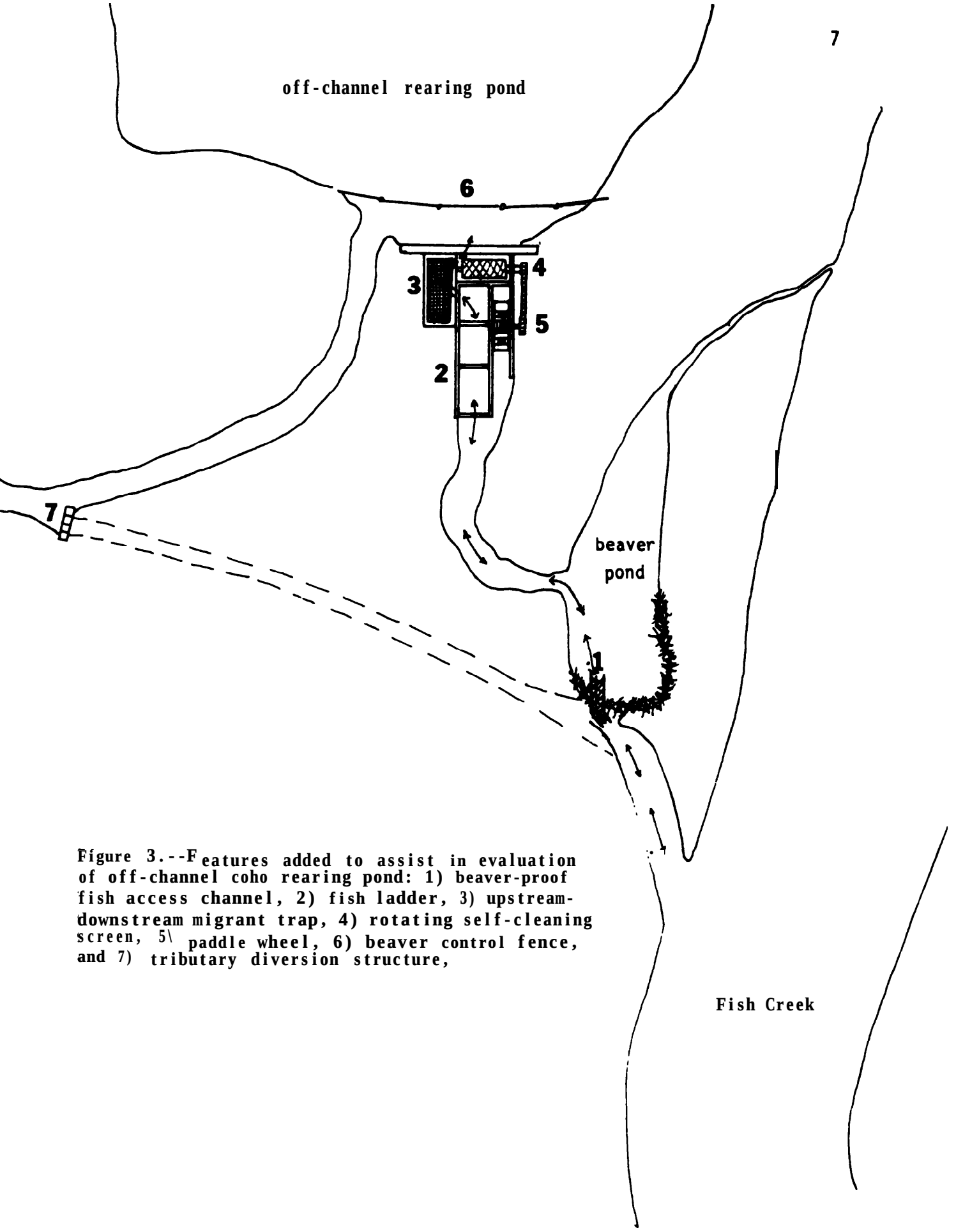


Figure 3.--Features added to assist in evaluation of off-channel coho rearing pond: 1) beaver-proof fish access channel, 2) fish ladder, 3) upstream-downstream migrant trap, 4) rotating self-cleaning screen, 5) paddle wheel, 6) beaver control fence, and 7) tributary diversion structure.

about 135 m in length and is capable of delivering about 35 l/set to the pond. The pond, which formerly was dry in summer, is approximately 90 m in length and 60 m in width. Depth varies from about 0.2 m to 1.25 m, and the surface area is about 0.5 hectares. Volume of the pond is about $3{,}600 m^3$. Water augmentation from the pipeline will maintain a near constant water level in the pond throughout the year. A second source of water augmentation for the pond was developed by diverting a small tributary stream at the northeast end of the pond. The stream formerly bypassed the pond but now flows directly into the north end.

METHODS AND MATERIALS

An important part of the habitat enhancement evaluation on Fish Creek was documentation of pre-improvement habitat characteristics and fish populations. Once these characteristics were established, changes in habitat and fish numbers associated with habitat improvement within the basin could be documented. Physical and biological surveys were also made before and after habitat improvements at specific sites.

Habitat Surveys.

The composition of physical habitat was measured by compiling the results of habitat surveys in five 0.5 km reaches in the basin (Fig. 4). Three reaches were located on mainstem Fish Creek between Wash Creek and mouth, and one each was located on Wash Creek and Fish Creek above the confluence of Wash Creek. Each reach was selected because it was representative of overall habitat conditions in Fish Creek and yet covered as much area planned for habitat enhancement projects as possible.

Five distinct habitat types were found in the reaches. These were riffles, pools, side channels, alcoves, and beaver ponds. Riffles and pools need no elaborate description even though many biologists prefer partitioning these two broad habitats into several additional categories. Side channels are found primarily above canyon constrictions and tributary junctions where sediments have accumulated for centuries. The stream often spreads out at high flow and forms multiple channels in these areas. The side channels are active at high flow in winter and

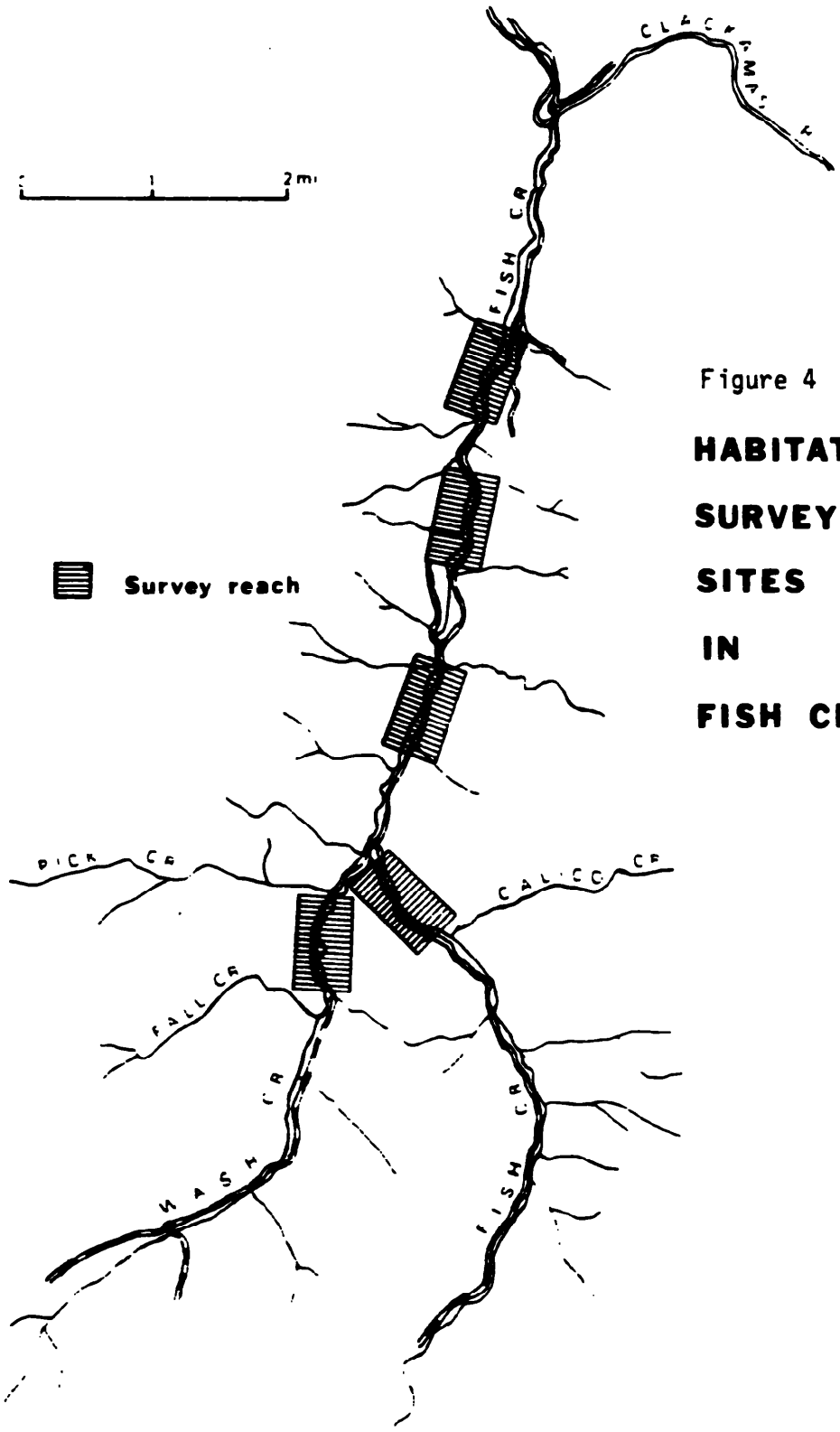


Figure 4

HABITAT SURVEY SITES IN FISH CREEK

spring, but are usually intermittent or dry in Fish Creek during the SUMMER. The water is slow moving at low flow. aLCOVES are formed along the edges of the main channel. They are quiet water habitats which are formed at high flows by eddy currents below a cascade, downed tree, or boulder. These four habitat types are preferentially occupied by the three anadromous fish species present in Fish Creek.

Physical habitat was measured by compiling results of the five 0.5 km reach surveys in the basin. Surface area and water volume of the five habitat types in each reach was measured. Results were extrapolated to the rest of the basin accessible to anadromous fish to estimate total habitat in each category available to anadromous fish. The sampling scheme inventoried about 15 percent of the basin.

Fish Population Estimates.

Fish population estimates for the portion of the basin accessible to anadromous salmonids were made by sampling juvenile salmonids in individual habitat types at 8 locations in the basin (Fig. 5). Fish populations were estimated separately for 36 habitat units (one habitat unit is one riffle, pool, side channel, alcove, or beaver pond) and then extrapolated to the basin based on previous estimates of total available habitat.

Populations of juvenile salmonids in each habitat unit were determined by installing 0.47 cm^2 mesh (3/16") block-nets at the upstream and downstream boundries of each site and electrofishing with a Smith-Root Type VII D.C. Shocker.

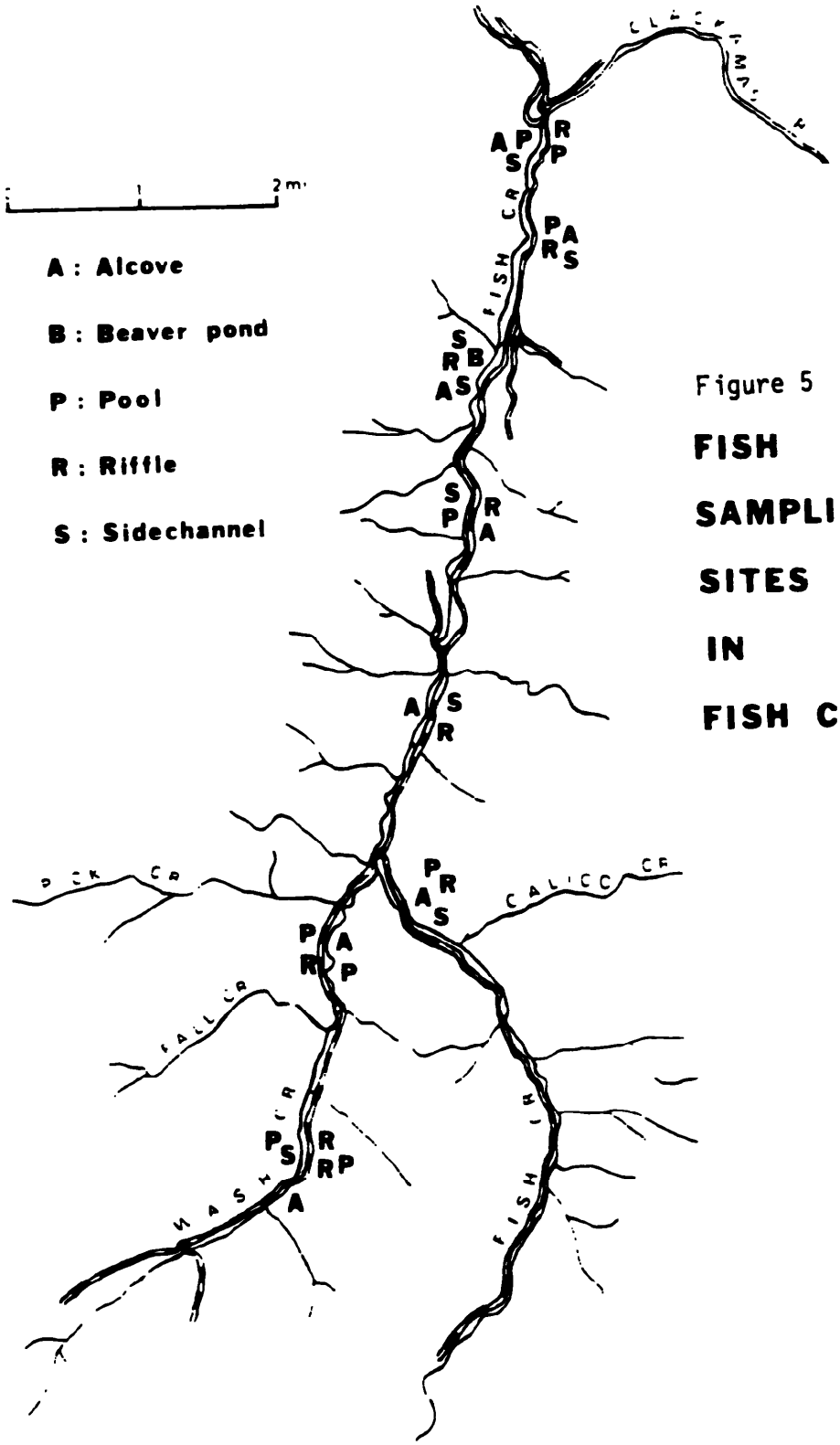


Figure 5

FISH SAMPLING SITES IN FISH CREEK

Population estimates were calculated by using a multiple pass removal method called the maximum weighted likelihood population estimation described by Carle and Strub (1978). Each pass included electrofishing from the downstream block-net to the upstream net and return. The sampling concluded when the succeeding catch was less than one-half of the previous catch.

Each salmonid was measured to the nearest millimeter (fork length) and the first 50 of each species at each site were weighed to the nearest tenth of a gram on an Ohaus Dial-O-Gram balance. Weights for additional numbers that were measured only were determined by using length/weight frequency calculations involving the first 50 fish weighed and measured.

Smoit Production Estimates

An estimate of smolt production for steelhead and coho in the basin was calculated from electrofishing data and habitat surveys. First, the area and volume of habitats measured in the five 0.5 km reaches was extrapolated to estimate the total area (m^2) and volume (m^3) of the five habitat types availabie to anadromous fish in the basin. Next, the mean density of juvenile salmonids in each age-class of each species was determined from quantitative data collected from 36 individual habitat units. These data were then applied to the total area and volume in each habitat type to estimate the total number and biomass of juveniles rearing in the basin. Finally, smolt output was estimated for steelhead by applying a survival factor in the number of age l+ fish in the system in September to estimate the number that would survive to smolt in May of

the following year. An identical procedure was used to estimate smolt output for coho. The survival factors applied to I+ steelhead and 0+ coho juveniles were 0.50 (Personal communication, T. Johnson, WDG) and 0.63 (Skeesick, 1970), respectively.

Rock Berm Improvements.

Physical Surveys--Physical habitat surveys designed to document changes in channel bed topography and substrate size distributions were completed at 21 sites in Fish Creek in the summer of 1983, before and after construction of rock berms. Each pre-construction survey will be used to monitor immediate and long-term changes in habitat resulting from berm construction.

These surveys consisted of longitudinal and transverse profiles, substrate mapping, and photographic records. Prework surveys were accomplished within 30 days prior to construction and post work surveys were completed within 14 days after construction. Additional surveys will be scheduled annually at low summer flow.

Each site received a general survey which consisted of a single longitudinal profile traversing the project area at the location of the thalweg. Transverse profiles were located at specified intervals, generally bracketing berm sites.

Additionally, at each site a more intensive survey grid was established consisting of three longitudinal profiles and five transverse profiles. These grids were located over a series of berm sites. Data on bottom elevations, substrate composition, and water depth were taken at 1 m intervals on the grid.

Substrate was mapped at both genera7 and intensive survey areas, bracketing a71 berm locations. Substrate mapping differentiated the bed into four size classes, boulders (~256 mm), cobbles (256 to 64 mm) gravels (64 to 4 mm), and sands z mm) (Wentworth Scale). Amounts of each and their locations were recorded.

Photo points were established to provide qualitative photographic evidence of substrate and topographic changes.

Biological Surveys--Fish population structure and biomass were determined at each berm site prior to construction using the techniques described earlier. The initial post construction surveys will be completed in the summer of 1984.

Off-Channel Habitat Improvement.

A number of features were added to the off-channel coho rearing pond during the evaluation effort in 7983. These included a fish ladder to allow adult and juvenile salmonids access to and from the pond, an upstream-downstream migrant trap, a tributary diversion structure to enhance spawning area in a pond inlet, beaver-proof access through a beaver dam between the pond and Fish Creek, and a beaver control fence near the pond outlet.

Fish ladder-8 fish ladder was constructed in the outlet stream from the pond in the fall of 7983 (Fig. 6). The structure is built of 10 cm x 75 cm timbers and lined with 13 mm thick plywood. The ladder is 8 m long, 0.8 m in width and contains four jump-pools to assist salmonids migrating to and from the pond. Each jump-pool is 50 cm deep and the maximum elevation between pools is 20 cm.

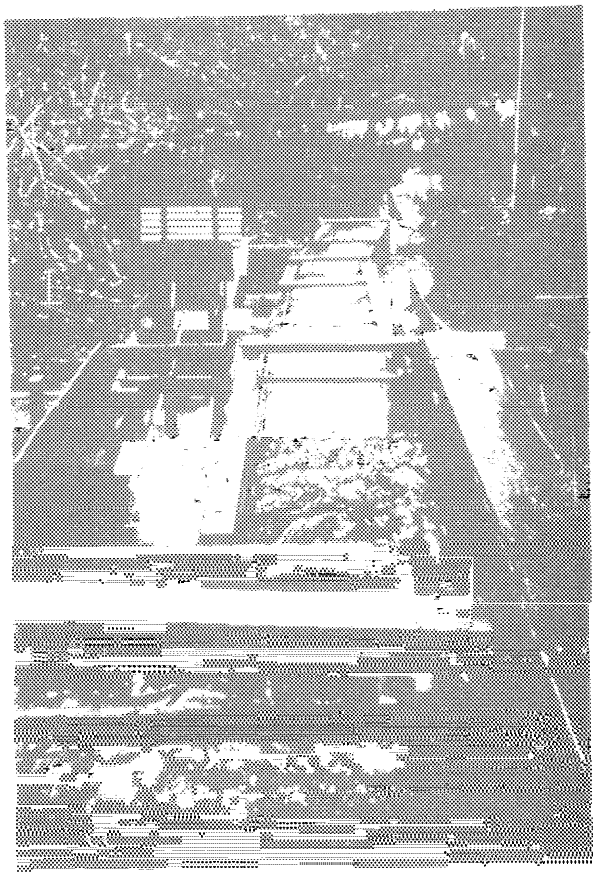


Figure 6A.--Fish ladder and trap at outlet of off-channel rearing pond.

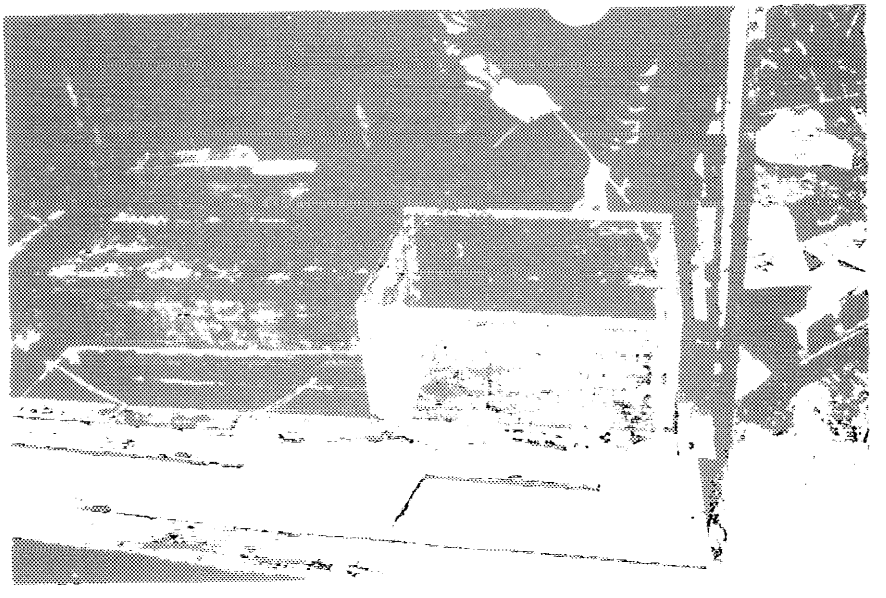


Figure 6B.--Trap baskets used to collect upstream and downstream migrant salmonids at the off-channel rearing pond.

Migrant Trap--A rotating drum screen 60 cm in diameter by 90 cm long at the head of the ladder diverts upstream and downstream migrants into two screen trap boxes adjacent to the ladder (Fig. 6). When the trap boxes are removed migrants are free to move through the trap to and from the pond. When the trap is being fished, the boxes are arranged so that upstream and downstream migrants are captured and held separately.

Tributary Diversion Structure--A small east aspect tributary with main channel draining to Fish Creek 50 m north of the pond was redirected with a small concrete diversion dam (Fig. 7) into an overflow channel draining into the pond. The diversion dam is approximately 2 m in width and 30 cm in height and has reversed the role of the two channels. The main channel now flows directly into the north end of the pond.

Beaver-Proof Access--Adult and juvenile salmonids moving from Fish Creek into the rearing pond must traverse a small beaver dam and pond enroute. The stick dam blocks upstream access at moderate to low flow because water percolates evenly through a broad expanse of the dam. To combat this problem, sticks were removed from a 0.5 m width on top of the dam and two parallel hogwire fences were constructed through the opening (Fig. 8). Each fence extends about 4 m down the outlet channel from the dam and 4 m into the beaver pond. The fences deter beavers from closing the breach in the dam and maintain open access for migrating fish.

Figure 7/L--Lou-head dam used to divert tributary stream into the off-channel rearing pond.

Figure 7 B.--Coho spawning habitat in inlet to off-channel rearing pond.

Figure 8.--Fenced salmonid access channel through beaver pond below off-channel rearing pond.

Beaver Control Fence--Beavers colonized the coho rearing pond soon after it was filled so precautions were taken to prevent beavers from damming the outlet at the mouth of the fish ladder. A hogwire fence 15 m long and 1.2 m high was installed across the outlet end of the pond about 3 m from the opening to the ladder. The fence does not impede movement of rearing fish but stops beavers moving toward the outlet structure.

Counts of Adult Salmonids in the Upper Clackamas River and Fish Creek.

Portland General Electric has maintained count records of adult and juvenile salmonids passing hydroelectric dams on the Clackamas River for more than two decades. The magnitude and timing of runs into the upper Clackamas system, and trends in run size were summarized from these records.

Counts of spawning adult salmonids in Fish Creek were made in the 1981-82 and 1982-83 seasons at approximately bimonthly intervals in the fall and at irregular intervals thereafter as weather and water conditions in winter permitted. Counts were made in five one km reaches, four in Fish Creek and one in Wash Creek. One reach contained the Suspender Timber Sale. Observations were also made outside of these reference areas.

Gravel Quantity.

Estimates of gravel quantity in Fish Creek and Wash Creek were made in the fall of 1982. Separate estimates of gravel available for steelhead, coho, and chinook were made. Since the species spawn at

different times of year, different flow levels, and utilize slightly different gravel sizes each of these variations was taken into account when quantifying m^2 of usable gravel. Only gravels of the correct size in the correct position for spawning and with the proper water depth and velocity at the correct time of year were included for each species.

Gravel Quality.

Relatively new equipment and techniques were used to assess gravel quality. A tri-tube freeze-core sampler was used to extract gravel cores for analysis. Sampling was conducted at two natural spawning areas and at rock berms constructed by the Forest Service in 1981 (Fig. 9). Eignteen core samples were collected in 1982 and each core was subdivided into three 10 cm depth increments. Quality estimates of each subsample were made by sorting the gravel through a series of sieves and calculating a quality index (f) based on geometric mean particle size and fort ing coefficient of the samples. The higher the calculated quality index number the higher the quality of the gravel. A rough prediction of survival to emergence can be made by relating the quality index number to past laboratory survival studies (Fig. 10).

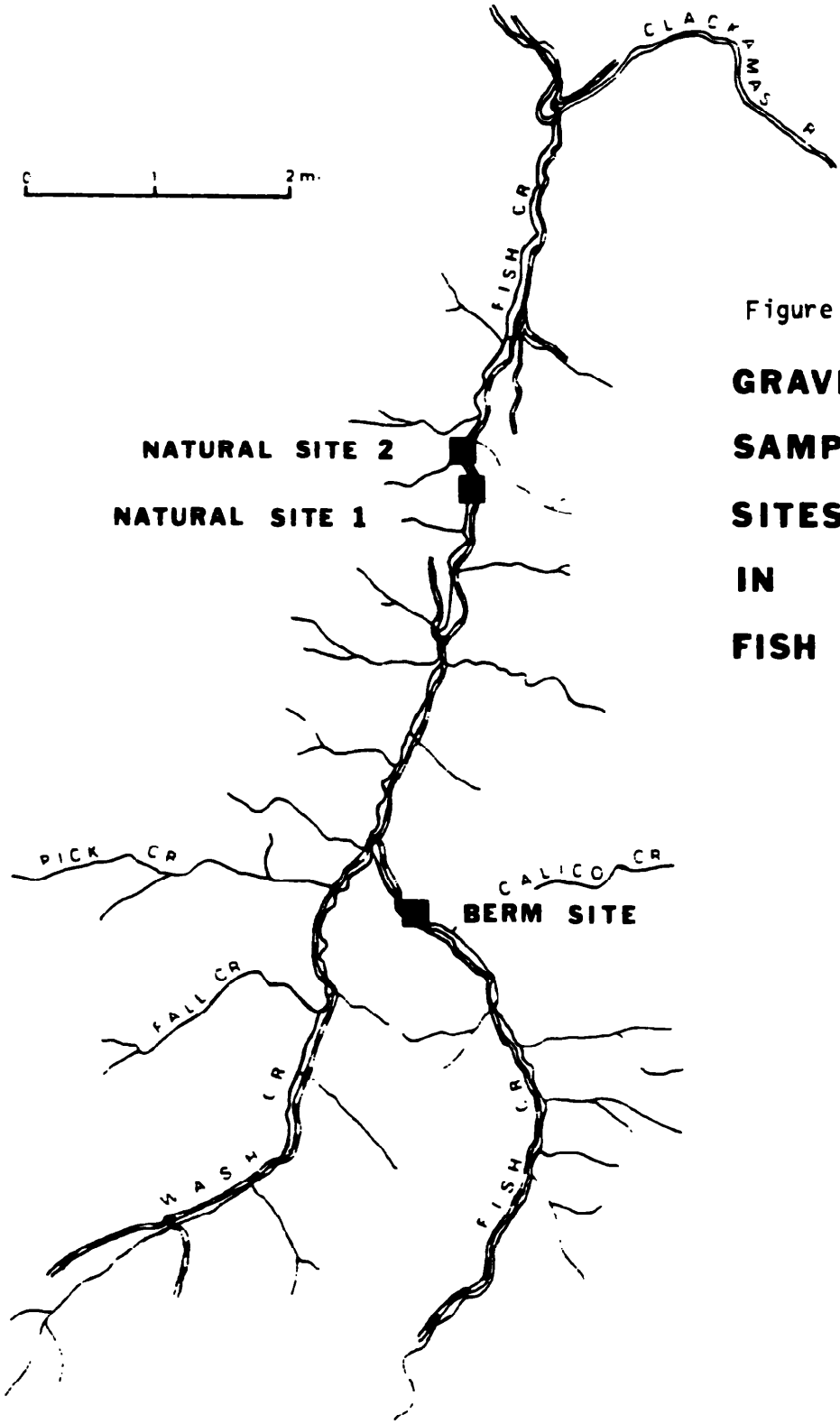


Figure 9

GRAVEL SAMPLING SITES IN FISH CREEK

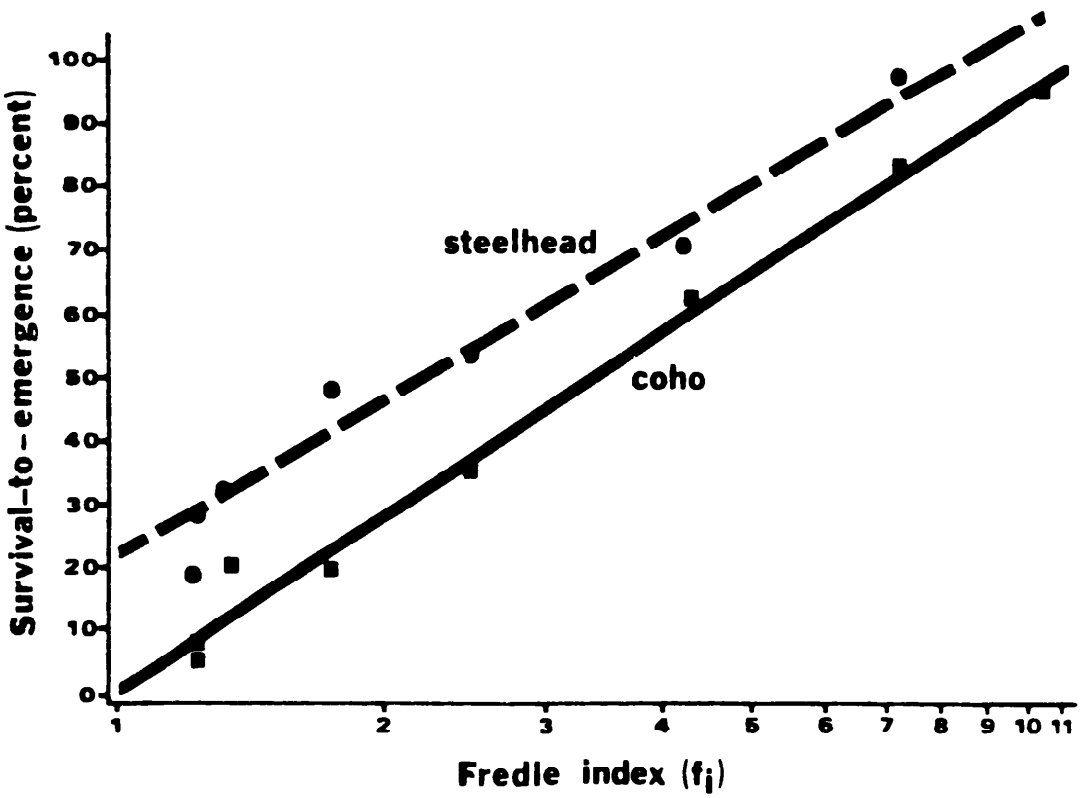


Figure 10.--Relationship between fredle index (f_i) numbers and survival-to-emergence of coho salmon and steelhead trout (semilog plot, lines fitted by eye; based on data of Phillips, R. W., R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Am. Fish Soc. 104(3):461-466).

RESULTS

Size and Timing of Salmonid Runs in the Clackamas River

Steelhead-Steelhead historically entered the upper Clackamas River above North Fork Dam in March, April, and May and spawned in tributary streams, including Fish Creek, soon after arrival. These were primarily winter-run fish that ascend streams from the ocean between November 1 and April 30. After migration through the lower Columbia, Willamette, and Clackamas rivers, peak numbers of fish arrived in the Upper Clackamas in late April and early May. Prior to 1971 more than 90 percent of the run (average sixe-2,000 fish, 1960-1970) passed North Fork Dam during this time period (Table 1).

A major steelhead hatchery program was initiated on the upper Clackamas in 1971 which has changed both the size and timing of the runs (Fig. 11; Tables 1 and 2). The run now contains both winter-run and summer-run steelhead and shows two distinct peaks of passage at North Fork Dam. The total annual run has increased substantially (average 4,200 fish, 1971-1980) with significant numbers of fish passing in all months between March and September. Major peaks now occur i May and July. The steelhead run into Fish Creek is still composed primarily of Hinter-run fish, but several summer-run fish were observed in large pools of the lower mainstem in 1982 and 1983, and one was seen in Wash Creek.

Coho Salmon--Coho salmon pass through the ladder at North Fork Dam from September through March annually. Peak passage occurs in November on most years (Fig.12; Tables 3 and 4). The numbers of coho using the upper Clackamas Basin have declined dramatically in the past decade.

Figure 11

COUNTS OF UPSTREAM MIGRANT STEELHEAD AT NORTH FORK DAM, CLACKAMAS RIVER

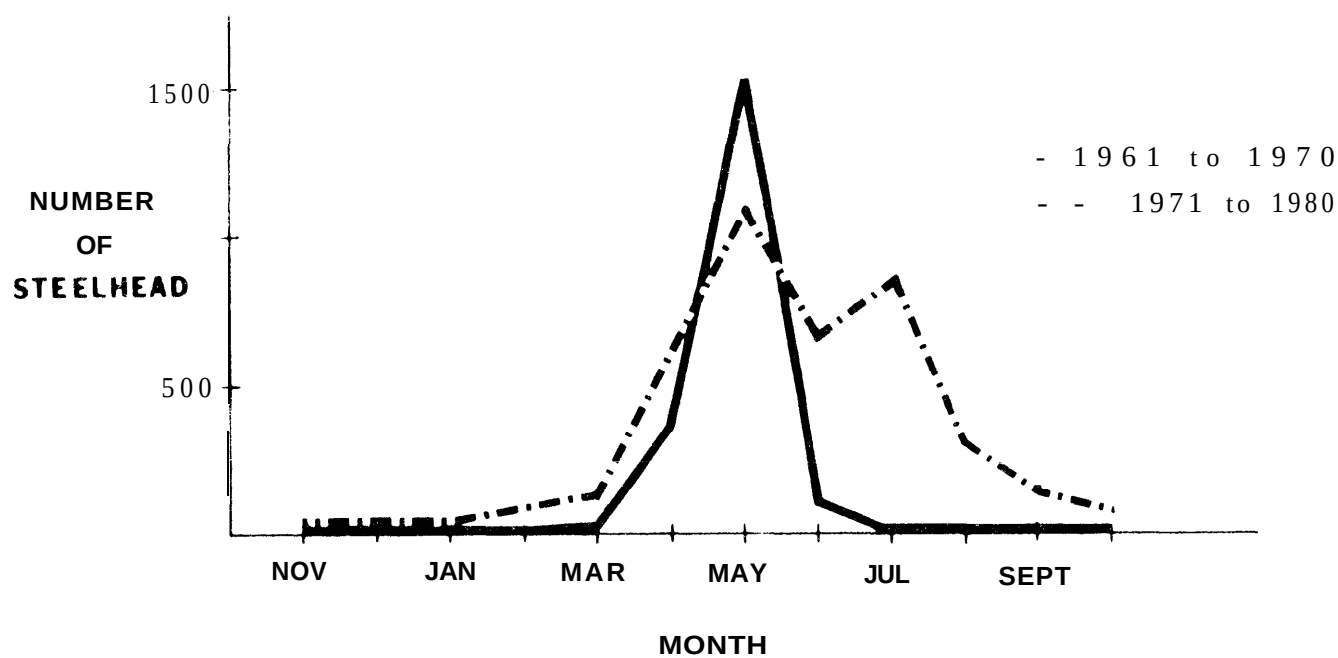


Table 1.--Counts of upstream migrant steelhead at North Fork Dam, Clackamas River, 1960-61 to 1969-70.

	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Total
1960-61	0	0	0	0	1	343	1,788	72	0	0	0	0	2,204
1961-62	0	0	0	0	1	1,506	2,502	351	0	0	0	0	4,360
1962-63	1	0	0	2	11	94	2,069	60	3	1	1	4	2,246
1963-64	1	0	1	0	0	218	1,554	109	2	0	0	0	1,885
1964-65	0	3	0	5	0	196	1,312	36	0	0	0	0	1,552
1965-66	3	0	1	0	0	2	1,158	126	0	0	0	1	1,291
1966-67	0	0	1	3	2	28	608	40	3	0	0	2	687
1967-68	3	3	2	10	5	35	721	11	0	1	1	8	800
1968-69	16	17	4	2	32	341	1,707	117	0	0	1	1	2,318
1969-70	10	13	3	30	81	946	1,692	35	0	0	1	3	2,813
Average	3.4	3.6	1.1	5.2	13.3	370.9	1.519.1	95.7	0.8	0.2	0.4	1.9	2,016

Table 2.--Counts of upstream migrant steelhead at North Fork Dam, Clackamas River, 1970-71 to 1982-83.

	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Total
1970-71	14	6	86	133	702	1,712	2,514	182	0	0	0	0	4,352
1971-72	4	20	18	64	62	559	1,784	127	88	88	19	6	2,839
1972-73	21	8	2	7	49	979	834	13	8	18	18	13	1,965
1973-74	7	2	9	7	11	132	451	174	408	208	44	10	1,493
1974-75	32	15	33	11	13	394	1,101	1,063	867	206	30	30	3,795
1975-76	14	55	26	11	60	350	696	484	651	254	88	9	2,698
1976-77	8	0	0	118	217	740	849	1,281	986	295	196	137	4,827
1377-78	145	139	75	177	515	822	769	1,640	984	348	533	94	6,241
1978-79	11	231	7	151	177	458	1,048	1,210	1,459	340	330	401	5,818
1979-80	7	---	170	116	136	853	1,047	506	3,087	1,314	364	137	7,737
1980-81	0	733	125	250	291	637	1,446	1,732	7,310	223	98	71	7,411
1981*-82	60	13:	25	8	68	456	1,171	1,767	1,426	325	95	45	5,581
1982-83	3	0	1	21	34	368	---	---	---	---	---	---	---
Average	29.3	10.01	41.1	82.2	141.7	611.9	1,142.7	844.1	1,022.4	307.4	151.3	79.4	4,563.5

Figure 12

COUNTS OF UPSTREAM MIGRANT COHO AT NORTH FORK DAM, CLACKAMAS RIVER

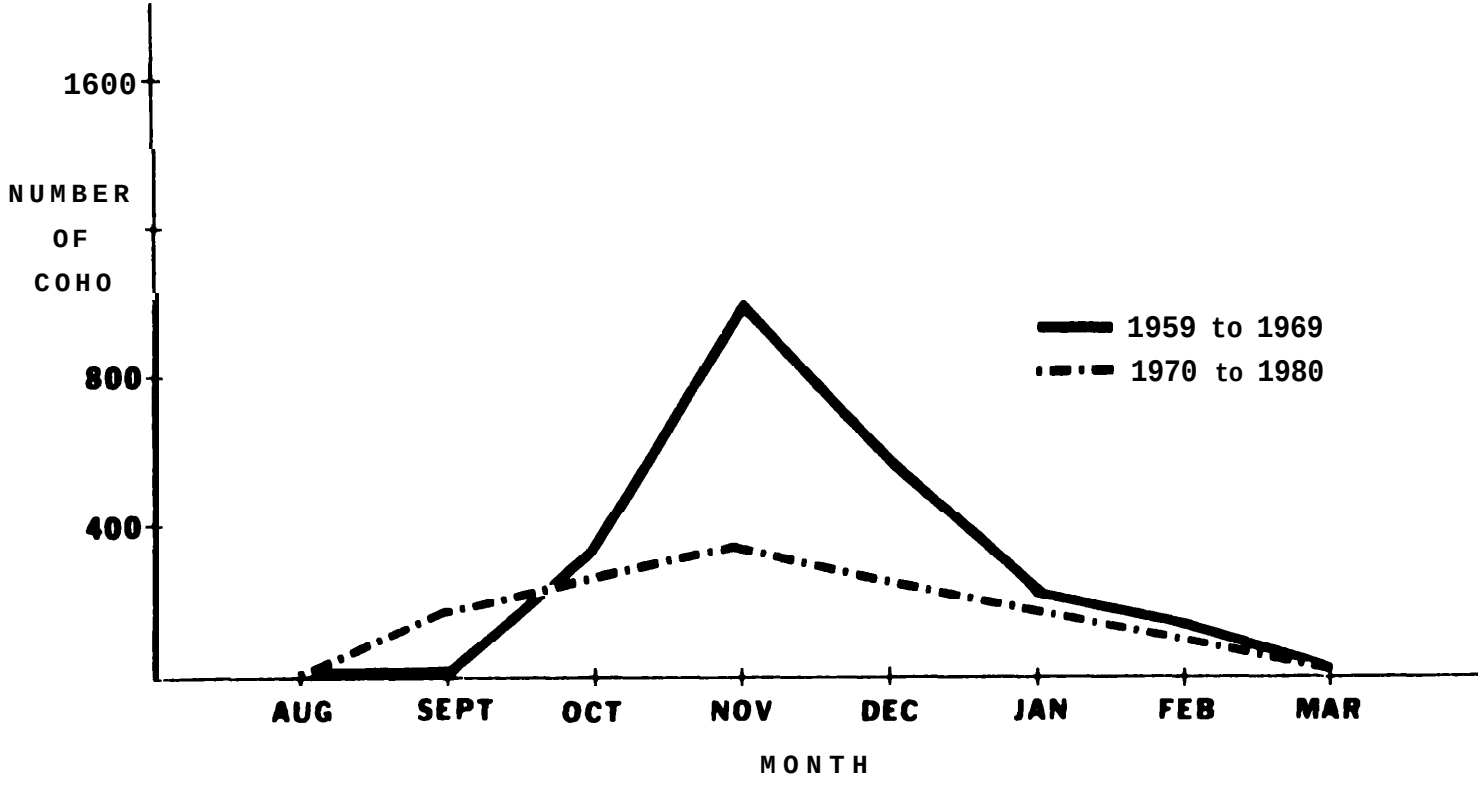


Table 3.--Counts of upstream migrant coho at North Fork Dam, Clackamas River, 1959-60 to 1968-69 (total includes jacks).

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1959-60	0	0	25	609	394	126	176	0	1,330
1960-61	0	0	433	1,227	155	278	91	1	2,185
1961-62	0	1	95	699	855	226	312	1	2,189
1962-63	0	0	234	1,612	933	123	217	1	3,119
1963-64	0	1	189	1,032	246	337	74	0	1,879
1964-65	0	25	234	749	1,043	228	197	0	2,476
1965-66	0	40	563	2,137	423	718	58	0	3,939
1966-67	0	1	174	308	245	39	11	0	778
1967-68	1	0	441	274	421	271	88	2	1,498
1968-69	0	91	979	2,163	1,047	192	216	8	4,696
Average	0.1	15.9	336.7	1,006.l	576.2	231.0	144.0	1.2	2,409

Table 4.--Counts of upstream migrant coho at North Fork Dam, Clackamas River, 1969-70 to 1982-83 (total includes jacks).

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1969-70	3	194	256	698	650	42	11	0	1,854
1970-71	0	242	1,053	843	341	257	16	0	2,752
1971-72			River Mill Ladder closed Aug. 1 - Nov. 5)						4,095
1972-73	7	239	102	436	205	86	17	5	1,097
1973-74	3	147	92	154	245	75	23	0	739
1974-75	0	38	67	464	304	61	3	0	937
1975-76	2	73	481	271	219	123	20	0	1,189
1976-77	3	111	117	130	137	394	308	27	1,227
1977-78	0	57	46	189	219	341	93	0	945
1978-79	0	214	139	56	143	7	266	2	827
1979-80	3	434	248	80	---	338	88	0	1,191
1980-81	0	122	130	943	1,422	585	40	0	3,242
1981-82	1	549	218	232	111	171	0	0	1,282
1982-83	46	916	602	123	384	739	137	2	2,949
Average	5.2	256.6	273.2	355.3	365.0	247.6	78.6	2.8	1,871.

During the 1960's the average annual run of coho exceeded 2,400 fish. Average runs during the 7970's fell below 1,700 fish and the average between 1975 and 1980 was about 7,000. The run might be trending upward again, average passage at N. Fork was 2,500 fish from 7980-7983.

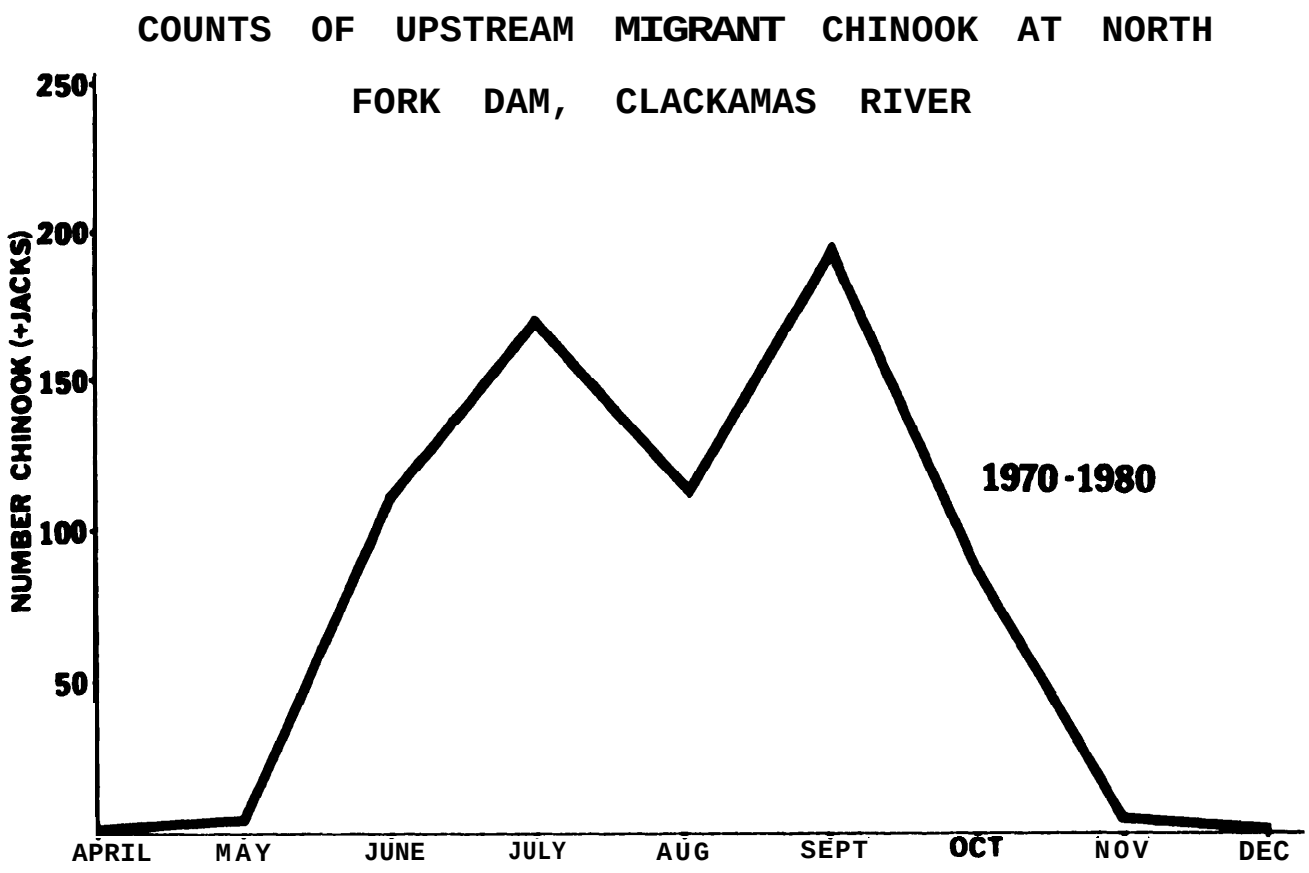
Chinook Salmon--Spring-run chinook salmon pass through the North Fork Dam ladder from May through October. Peak passage usually occurs in July or September (Fig. 13) and is related to streamflow and water temperature.

The numbers of chinook moving to the upper Clackamas have remained fairly constant over the past 20 years. During the 7960's average run size including jacks totalled about 580 fish, while totals in the 7970's averaged 640 fish. A record run exceeding 2,100 fish occurred in 1980.

quantity and Distribution of Spawning Gravels

The reaches of Fish Creek and tributaries accessible to anadromous salmonids are in large steep-gradient streams, consequently spawning gravels in the area are sparse and scattered. The substrate throughout the system is composed predominately of boulders and rubble with isolated patches of gravel suitable for spawning. Gravels suitable for reproduction are often found along the stream margin where physical features such as boulders and large organic debris have caused deposition of gravels. Spawning gravels also occur at the tail of some large pools and in a few side channels and braided sections of the main channel. There are few large expanses of spawning gravel and those that do occur are in the 7ower 2.5 km of stream. Most gravel occurs in 5 to 15 m^2

Figure 13


COUNTS OF UPSTREAM MIGRANT CHINOOK AT NORTH FORK DAM, CLACKAMAS RIVER
NUMBER CHINOOK (+JACKS)
250
200
150
100
50
1970-1980
APRIL
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC

pockets scattered throughout the system. A total of about 2,100 m^2 of spawning gravel is available to anadromous salmonids and boulder berm habitat improvements by the Estacada Ranger District in 7981 have added 35 m^2 (1.7 percent) to the total (Table 5). A previous survey completed in 1976 by Chuck Whitt (Mt. Hood N.F.) quantified spawning gravel resources at 971 m^2 for anadromous fish. Gravel resources appear to have increased substantially since that time.

Table 5. Spawning gravel in Fish Creek System, 1982.

Species	Natural Gravel [m^2]	Berm Gravel [m^2]	Percent increase
Chinook	190	0	0
Coho	569	0	0
Steelhead	1,348	35	3

The quantity of gravel available to the different species of anadromous salmonids in Fish Creek, and the spatial and temporal use of the gravels, varies considerably (Figs. 14 and 15).

Chinook were found to utilize the lower 5 km for spawning and have only about 200 m^2 of good gravel available (Table 5). Gravels used

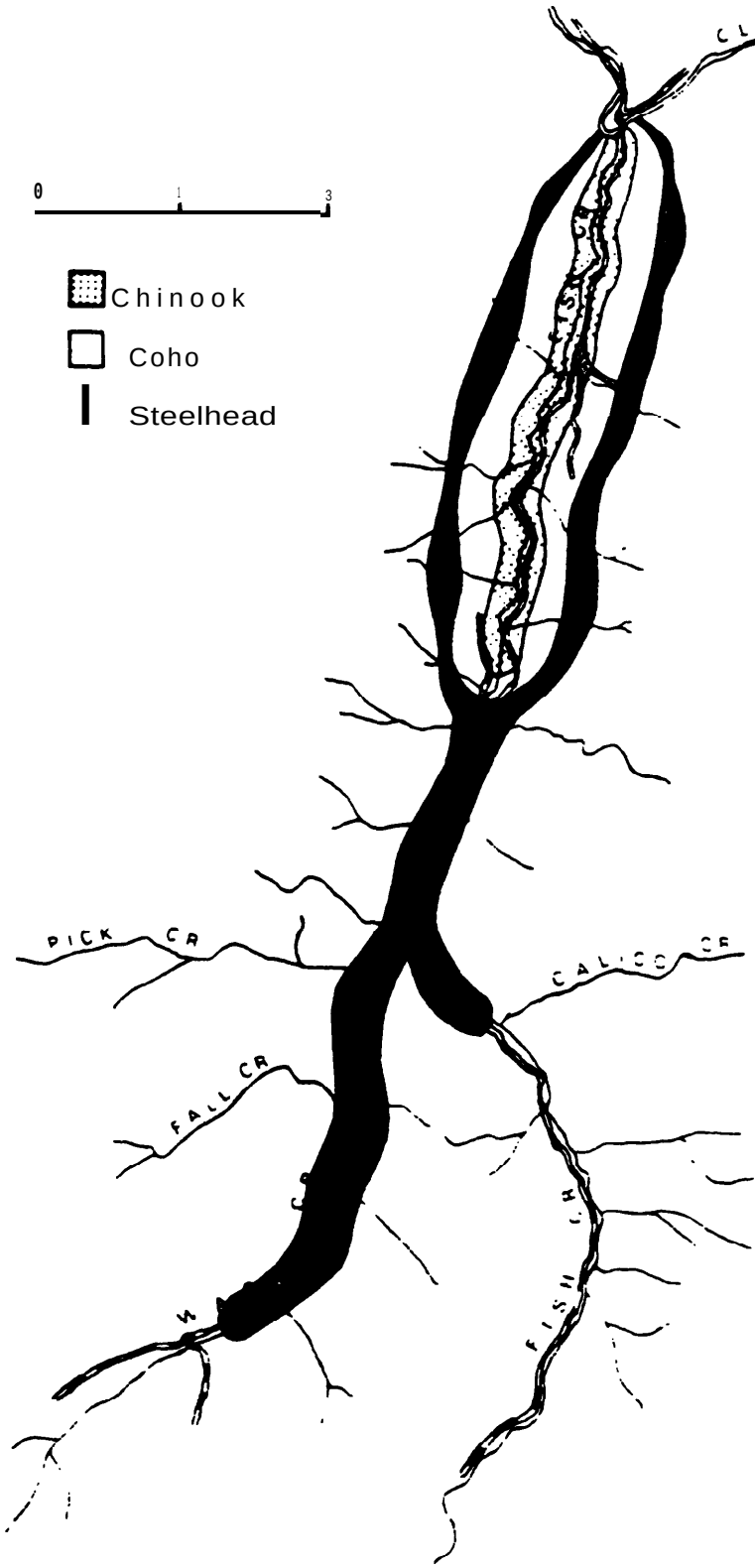
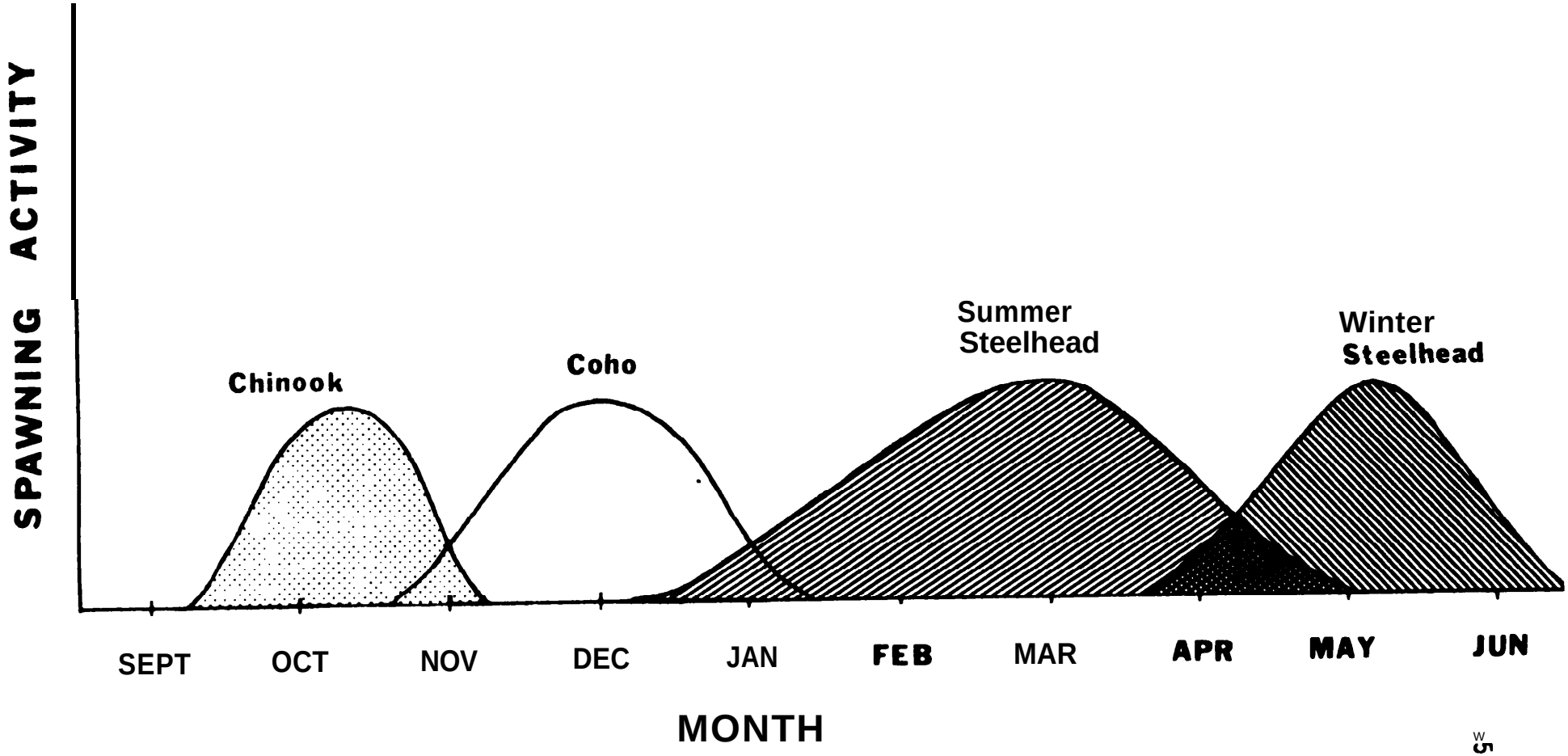


Figure 14

DISTRIBUTION OF SPAWNING SALMONIDS IN FISH CREEK

Figure 15

TIMING OF SPAWNING ACTIVITIES OF FISH CREEK SALMONIDS



range from about 2 to 75 cm in diameter. The number of chinook spawning in Fish Creek varies annually according to run size in the Clackamas River and timing of fall freshets. In some years, 1982 for example, available gravels appear to have been fully utilized (Table 6).

Table 6. Chinook salmon adults and redds observed on Fish Creek, 79814983.

	7981	7982	7983
Chinook Redds	31	83	11
Adult chinook	32	36	28

Coho salmon spawn primarily in the lower 5 km of Fish Creek, in late fall and early winter when streamflows are fluctuating from storm events. Consequently, not all of the 570 m^2 gravel potentially available to coho can be utilized at all times (Table 5). Yigh flow events during the spawning season restrict coho spawning to favored habitats along the stream margins, side channels, and lower reaches of small tributary streams (Fig. 16).

Quality of Spawning Gravels.

The objectives of examining the quality of spawning gravels on Fish Creek were threefold:

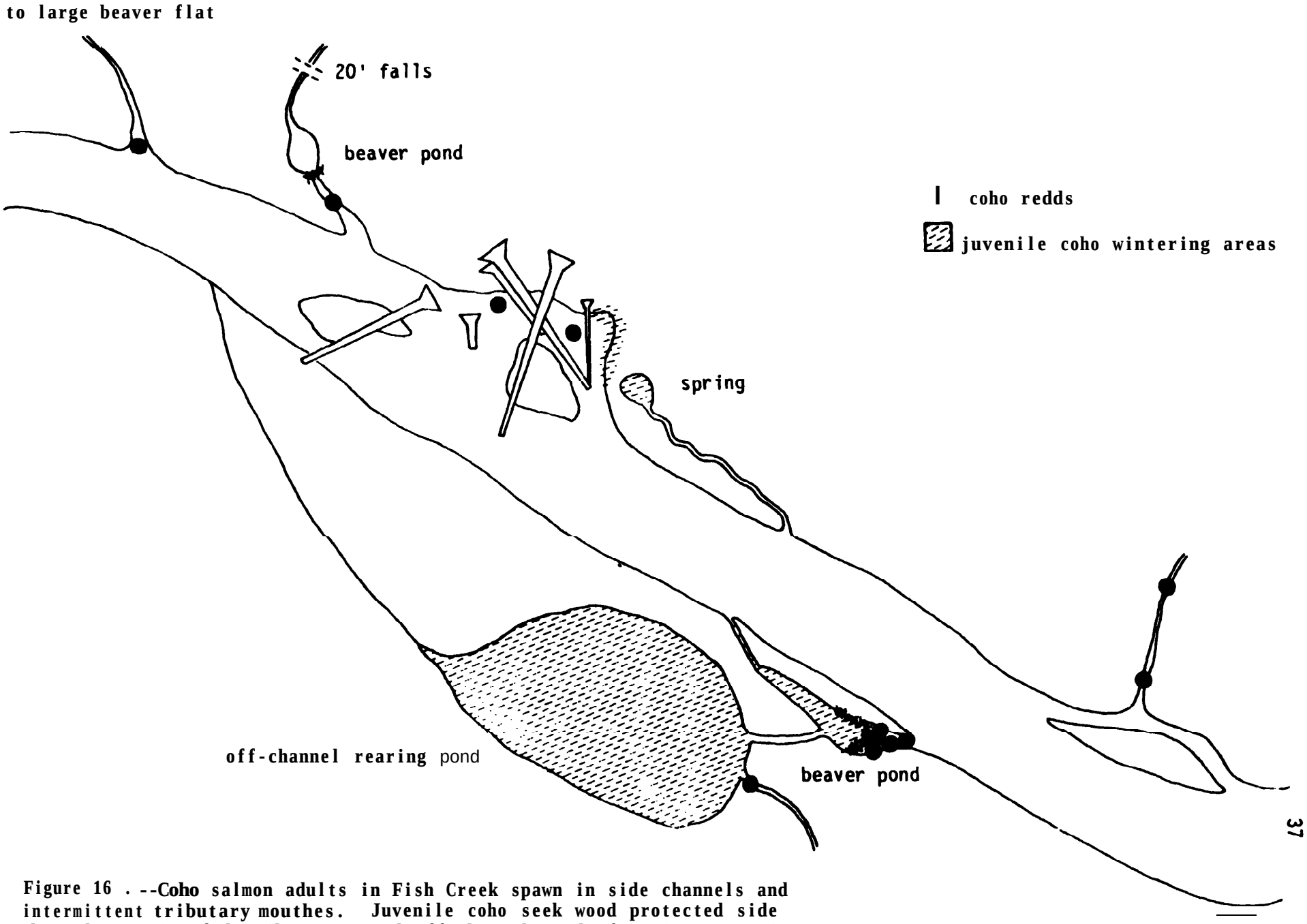


Figure 16 . --Coho salmon adults in Fish Creek spawn in side channels and intermittent tributary mouthes. Juvenile coho seek wood protected side channels, spring-fed tributaries and off-channel ponds for winter rearing areas.

(1) Estimate quality and potential survival of anadromous salmonids in natural gravels;

(2) Compare quality of natural gravels with quality of gravels impounded by the rock berm structures on upper Fish Creek; and

(3) Establish a baseline of gravel quality that can be monitored over time as timber management activities progress within the basin.

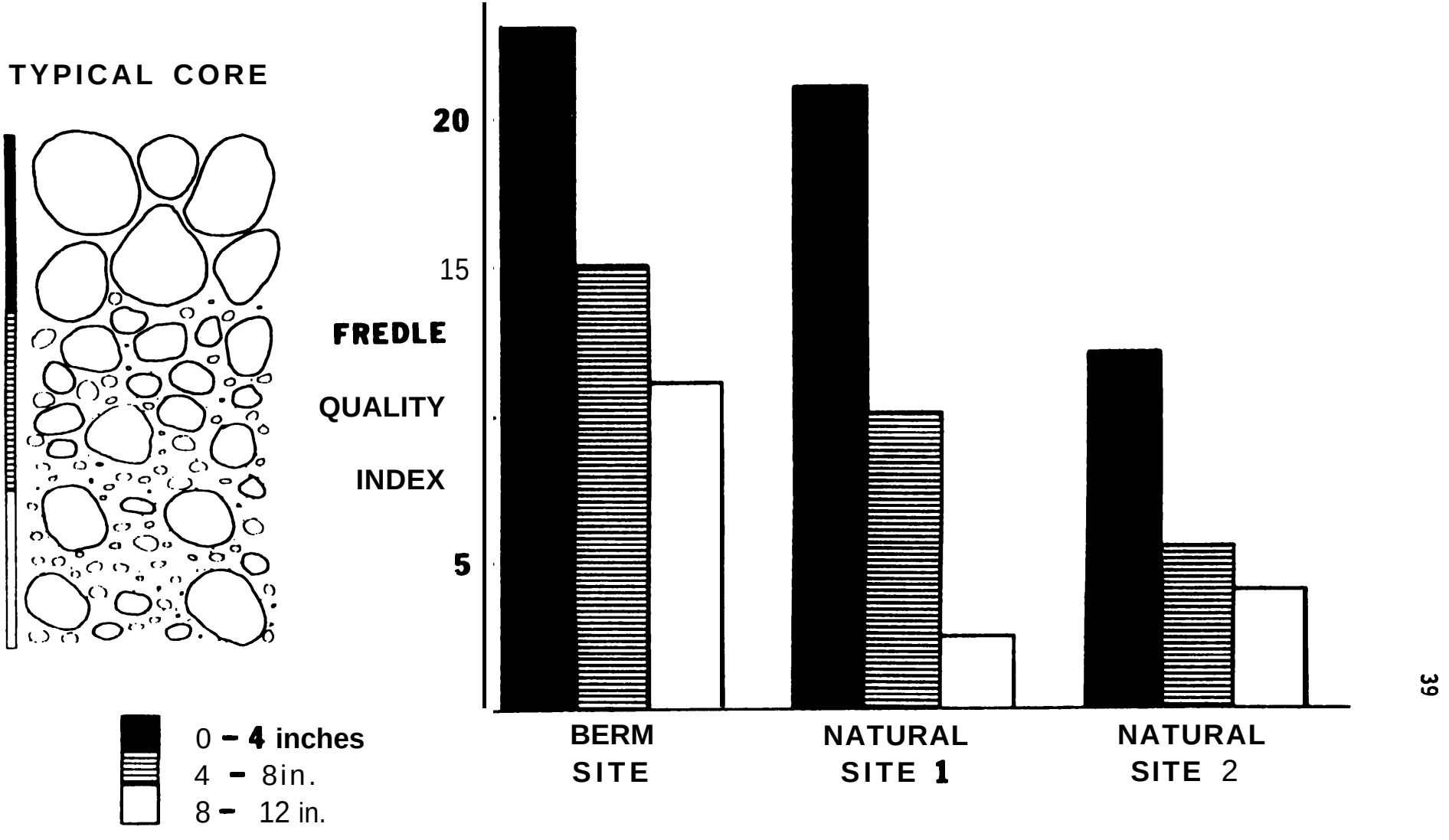
All gravels sampled, natural and berm-impounded, were high quality (Fig. 17). Survival to emergence would be expected to exceed 75 percent at all sites. The berm-impounded gravels were of slightly higher quality than natural gravels sampled. Steelhead eggs are buried about 20 cm deep by spawning females and emerging alevins must be able to work their way upward through pores in the gravel to emerge successfully. The top 20 cm of berm gravels exceeded a quality index number of 15 and near 100 percent survival would be anticipated there. Gravels at natural sites 1 and 2 should allow survival to emergence of about 95 and 75 percent, respectively.

Adeauacv of Gravel Resources

A primary need of any habitat enhancement program is identification of factors limiting fish production. The objective of initial enhancement efforts on Fish Creek was to increase spawning area for steelhead. A series of 5 rock berms constructed to catch gravels on upper Fish Creek were successful and 35 m^2 of good spawning area was added to the system. Steelhead are utilizing these gravels. The addition of these gravels, however, might not have enhanced steelhead

Figure 17

QUALITY OF SPAWNING GRAVEL IN FISH CREEK, 1982



production in Fish Creek. The balance between steelhead spawning and rearing area in Fish Creek appears to be near optimum at the present time (Table 7). Nearly 1,350 m^2 of gravel is available for spawning--enough to accomodate about 300 females. Assuming a sex ratio of 1.5 males per female, the steelhead run in Fish Creek required to fully utilize the gravel resources would be about 750 fish. At a 5 percent smolt to adult survival rate, 15,000 smolts would be required to produce a run of 750 adults. Twenty m2 of suitable habitat are required, on the average, to produce each smolt and the total available rearing area for smolts is about 308,000 m2. Rearing habitat then by paper estmate, is capable of producing about 15,400 smolts. Actual estimates of smolt production in 1982 and 1983 based on extensive field sampling were 15,040 and 15,800, respectively. Spawning habitat is capable of producing at least 19,800 smolts (Table 7), so rearing habitat rather than spawning habitat appears to be limiting steelhead production in Fish Creek. But the balance between spawning and rearing habitat is close and gravel area enhancement at the rock berms has added some assurance that spawning area in all years will be sufficient to seed or slightly overseed available rearing areas. It appears, however, that at the present time no additional enhancement of steelhead spawning areas is necessary.

Gravels available for chinook spawning might be inadequate to accomodate the run in some years. In 1982, 83 chinoom redds were counted in a total gravel area of only 200 m^2 scattered over 7.5 km of stream. Available gravels were totally utilized and additional spawning area probably would have been beneficial. While gravels appeared to be in

Table 7.--Relationship between spawning and rearing habitat for steelhead.

Parameter	Numbers
Steelhead spawning area required/pair	4.4 m^2
Steelhead spawning area in system	1,348 m^2
♀'s accomodated without redd superimposition	300
Total spawning population withl.5 ♂/♀	750
Rearing area required/smolt	20 m^2
Rearing area in system	308,000 m^2
Smolt accomodated in system	15,400
Eggs from 300 ♀s (2,200 eggs/ ♀)	660,000
Emergent fry (30% survival)	198,000
Parr (20% survival/yr	39,600
Smolts (50% survival/yr)	19,800
Expected adult return (5%)	990

Present spawning area can accomodate enough adults to fully seed the system.

short supply in Fish Creek, it is not known whether spawning area is presently limiting production of spring chinook in the upper Clackamas system, or whether additional gravels in Fish Creek would contribute to a larger chinook salmon run in the system. Determining the relationship between chinook spawning and rearing area is beyond the scope of this investigation because most juvenile chinook spawned in Fish Creek do not rear there. After emergence most move downstream to rear in the Claskamas River or large hydropower reservoirs downstream. By summer, few juvenile chinook remain in Fish Creek.

The relationship between spawning and rearing area for coho salmon has not been adequately defined. Coho spawning activity is limited to marginal habitats in the lower maintstem of Fish Creek where about 570 m^2 of gravel is available. Additional surveys are needed to determine how much of this gravel is actually available during the spawning season. Assuming all of it can be used, about 140 females could be accomodated on the gravels. Using Oregon Department of Fish and Wildlife survival estimates, 140 females would be expected to produce about 12,600 smolts. Fish population estimates in the system in 1982 and 1983 indicate a potential production of about 2,800 and 8,900 coho smolts, respectively. The increase in 1983 was due in part to a larger parent run that year and indicate that coho habitat in Fish Creek is underseeded. These data are tenuous but indicate that coho production is probably limited by 1) lack of adequate escapement, and 2) lack of suitable rearing habitat if spawning areas were fully utilized.

Distribution of Rearing Juvenile Salmonids in Fish Creek

There are three species of juvenile anadromous fish which utilize the Fish Creek basin for rearing. They are chinook salmon, coho salmon and steelhead trout. Juvenile chinook and coho salmon rear in the first 5.2 km of the Fish Creek Basin (Fig. 18). Steelhead trout juveniles are distributed throughout the entire 11.8 km of Fish Creek to the falls just above Calico Creek and 6.1 km of Wash Creek to the base of a waterfall. Chinook salmon juveniles are transient in the Fish Creek system. Most chinook move out of Fish Creek by late summer and rearing probably occurs in the mainstream Clackamas, hydropower reservoirs on the Clackamas, and in the Willamette River on their way to the sea. Coho salmon juveniles prefer side channels, alcoves, and quiet pools, most of which are located within 5.6 km of the confluence of Fish Creek and the Clackamas River.

Steelhead trout juveniles prefer fast water riffles which constitute the most abundant habitat type in Fish Creek. Young-of-the-year (0+) steelhead prefer the low velocity margins of riffles while older steelhead (l+) prefer to live and feed in deep swift habitats of boulder riffles.

Fish Creek Physical Habitat and Salmonid Populations-1982

Physical Habitat--Channel processes and landforms have created and maintained four basic habitat types in Fish Creek. These include riffles, pools, side channels and alcoves. Beaver ponds are a fifth specialized type of habitat. Riffle habitat made up about 83 percent of the total habitat surface area in Fish Creek in 1982 (Fig. 19). Pools

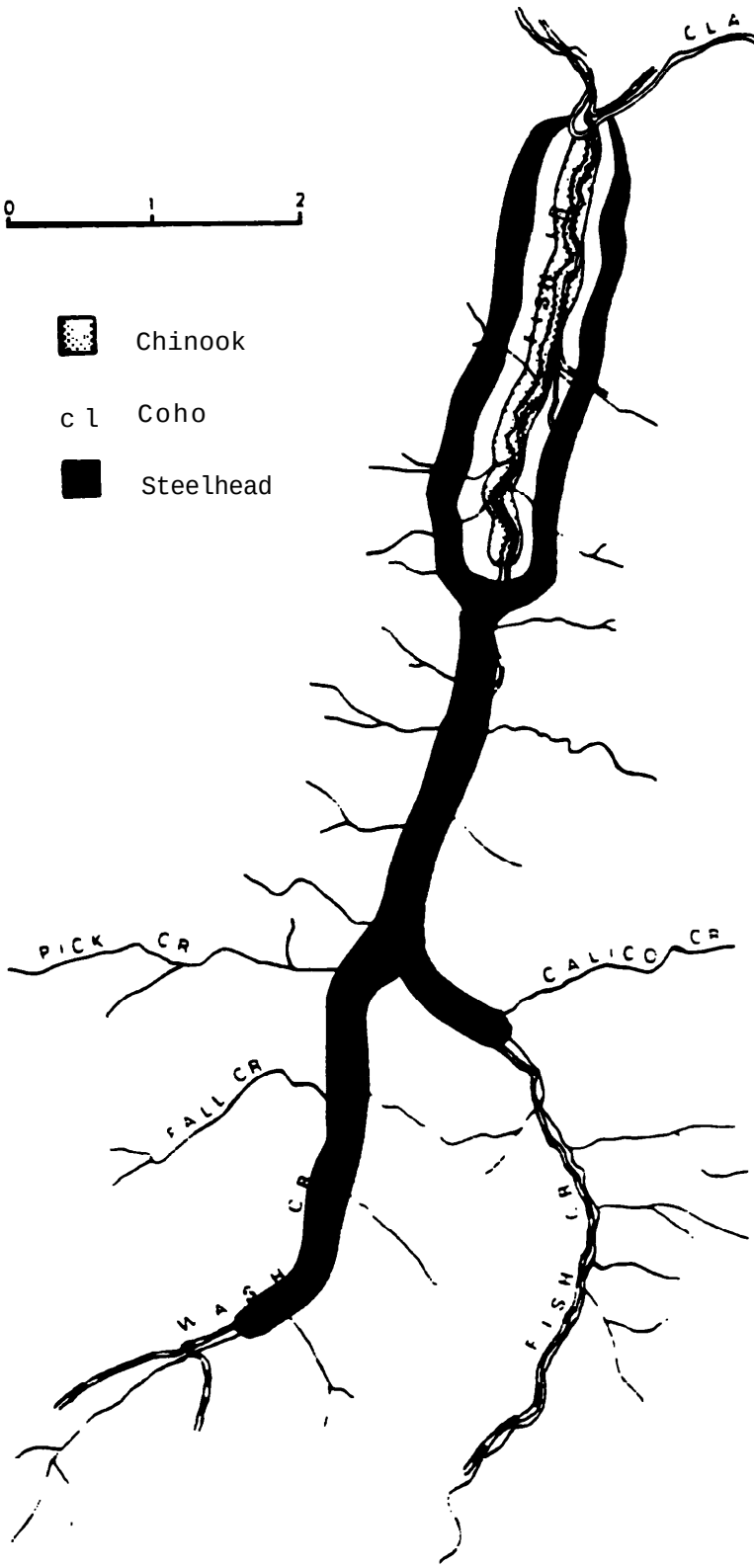
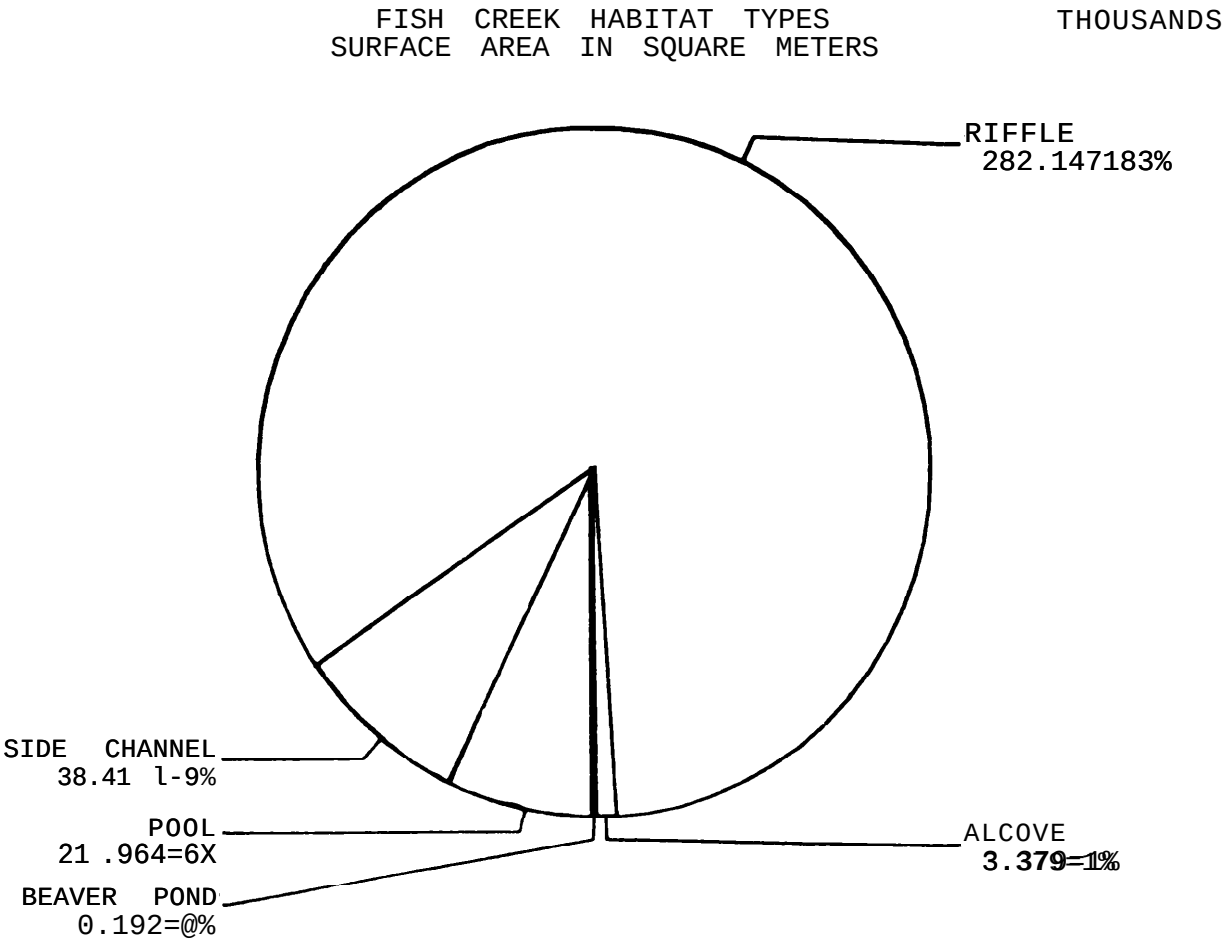


Figure 18

DISTRIBUTION OF JUVENILE SALMONIDS IN FISH CREEK

Figure 19


FISH CREEK HABITAT TYPES
SURFACE AREA IN SQUARE METERS
THOUSANDS
RIFFLE
282.147183%
SIDE CHANNEL
38.41 l-9%
POOL
21 .964=6X
BEAVER POND
0.192=@%
ALCOVE
3.379=1%

made up only 6 percent. The pool to riffle ratio is a low 1:14. Side channels make up 9 percent, quiet alcoves about 1 percent and a beaver pond on an old channel about 0.3 percent (Fig. 19). Quiet water habitats are scarce in Fish Creek.

Volume of water in the basin reflected the surface area habitat estimates closely (Table 8). Riffles accounted for 82 percent of the volume in the basin, the same as the relative area amount. Pools provided 7 percent of basin volume and side channels about 10 percent. Pools, as expected, accounted for more volume than surface area.

These values define a high gradient stream system with a few deep pools which are fast-moving plunge or scour pools at high water. Side cnannels are restricted to a few areas in the basin.

Salmonid Densities and Biomass--Steelhead trout were the most abundant salmonid in the basin in 1982. Fish Creek is an excellent stream for rearing juvenile steelhead since they prefer fast water habitats.

Steelhead trout juveniles account for 98 and 99 percent of the biomass of salmonids in the basins. Young-of-the-year or 0+ steelhead were the most abundant fish numerically. Even though yearling steelhead made up less than one-third the number of total salmonids, their biomass accounted for more than one-half the total salmonid biomass (Table 8). Coho salmon were a minor component of the rearing saimonids in Fish Creek. Coho represented about 2 percent of the total salmonid numbers and only about 1 percent of the biomass.

Table 8.--Area and volume of rearing habitat types in Fish Creek used by anadromous fish and their associated salmonid densities and biomass.

FISH CREEK 1982

SPECIES	HABITAT	AREA IN SYSTEM (m^2)	VOLUME IN SYSTEM (m^3)	NUMBER FISH ESTIMATE BY HABITAT	BIOMASS(g) FISH ESTIMATE BY HABITAT	#/m^2	g/m^2	#/m^3	g/m^3
COHO	Alcove	949	264	305	1,885	0.30	2.00	1.20	7.10
	Riffle	78,300	21,675	1,951	6,341	0.02	0.10	0.10	0.30
	Sidechannel	11,864	2,643	2,115	14,640	0.20	1.20	0.80	5.50
	Pool	3,796	1,850	131	1,286	0.03	0.30	0.10	0.70
	Beaver Pond	192	36	264	1,223	1.40	6.40	7.30	34.0
Total		95,101	26,468	4,766	20,565				
0+STHD	Alcove	3,379	814	1,808	4,119	0.50	1.20	2.20	5.10
	Riffle	282,147	66,716	146,952	432,927	0.50	1.50	2.20	6.50
	Sidechannel	30,4il	2,441	32,867	82,934	1.10	2.70	13.50	34.00
	Pool	21,964	11,390	8,082	21,807	0.40	1 .00	0.70	1.90
	Beaver Pond	192	36	1	8	0.01	0.04	0.03	0.20
Total		338,093	81,397	189,710	541,795				
1+STHD	Alcove	3,379	814	154	2,875	0.10	0.90	0.20	3.50
	Riffle	282,147	66,716	41,894	769,949	0.20	2.70	0.60	11.50
	Sidechannel	30,411	2,441	4,082	74,556	0.10	2.50	1.70	30.50
	Pool	21,964	11,390	4,028	89,088	0.20	4.10	0.40	7.80
	Beaver Pond	132	26	4	40	0.0:	0.20	0.10	1.10
	Total	338,093	01,397	50,162	336,508				

0+ steelhead utilized riffles and side channels preferentially. Side channels represented 9 percent of available habitat but 17 percent of the numbers and 15 percent of the biomass of 0+ steelhead utilized them. For this age group side channels were twice as important as the habitat area would suggest (Fig. 20).

Densities of 0+ steelhead were highest in side channels ($13.5/m^3$) (Table 8). Side channels were key habitats for newly emergent steelhead.

Yearling and older steelhead (1+) were mostly found in riffle; (84 percent). On a density basis, l+ steelhead occupied pools and riffles ($0.2/m^2$) about equally, although larger individuals of this age group were found in both side channels and pools. Since size is an indication of dominance, the largest 1+ steelhead were found preferentially in these minor habitat types (Table 8, Fig. 21).

Coho salmon utilized different habitats than steelhead trout. Even though 41 percent of the total coho salmon juveniles were found in riffles (Fig. 22), they were utilizing the margins of the stream and were most abundant in pocket pools on the edge and within root wads or debris which afforded cover. The biomass of coho in riffles was only 25 percent of the total. This indicates that the smaller individiuals were occupying this less preferred habitat types (Fig. 22). The largest individual coho salmon were found in alcoves and pools (Table 8). The beaver pond which amounted to only 0.3 percent of the total habitat was rearing 6 percent of the total coho salmon individuals and 5 percent of the total coho salmon biomass. The importance of this habitat type to rearing coho far exceeds its general availability. Beaver ponds as well

Figure 20.--Age 0+ steelhead trout numbers and biomass per habitat type in Fish Creek, 1982.

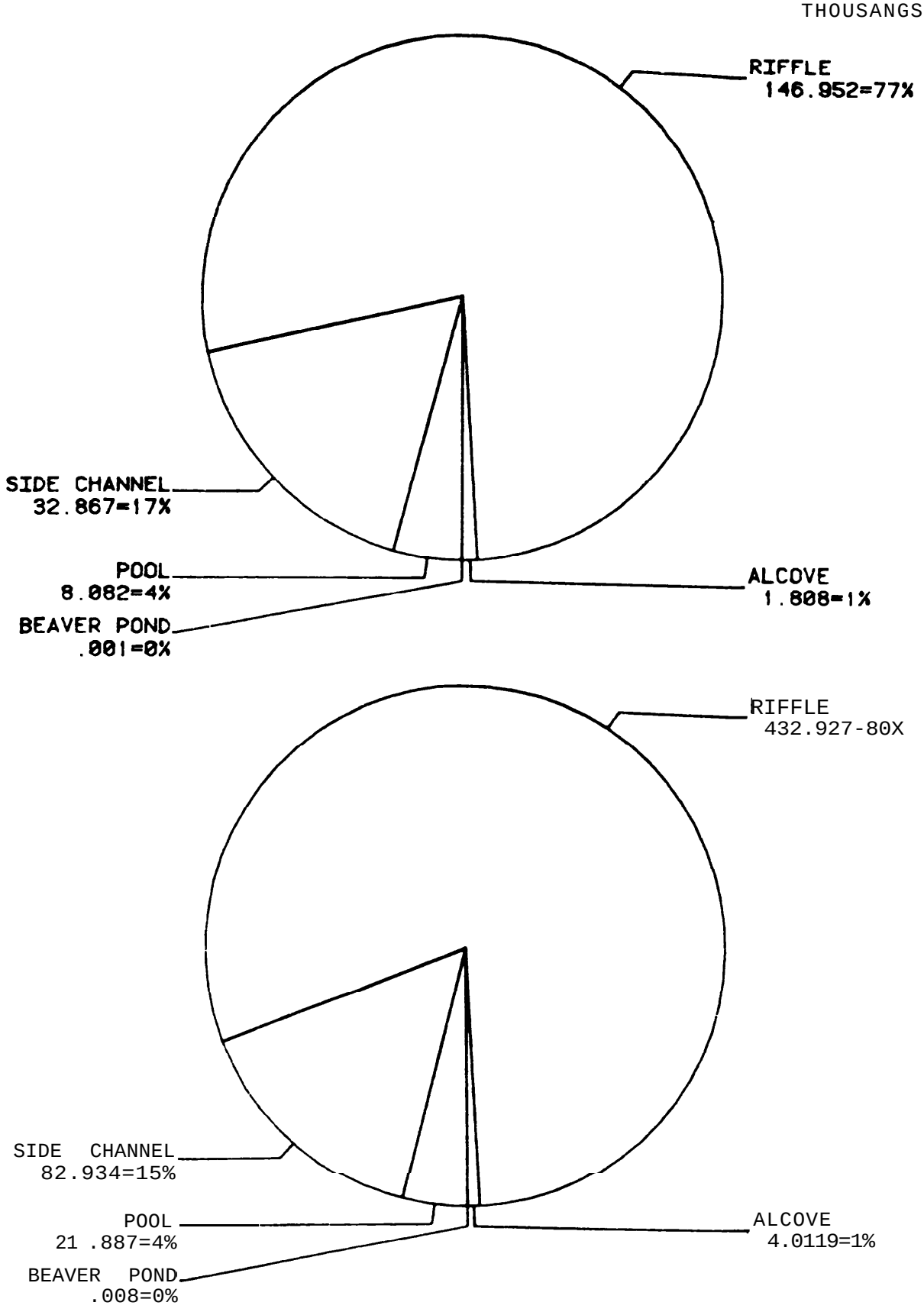


Figure 21.--Age 1+ steelhead trout numbers and biomass per habitat type in Fish Creek, 1982.

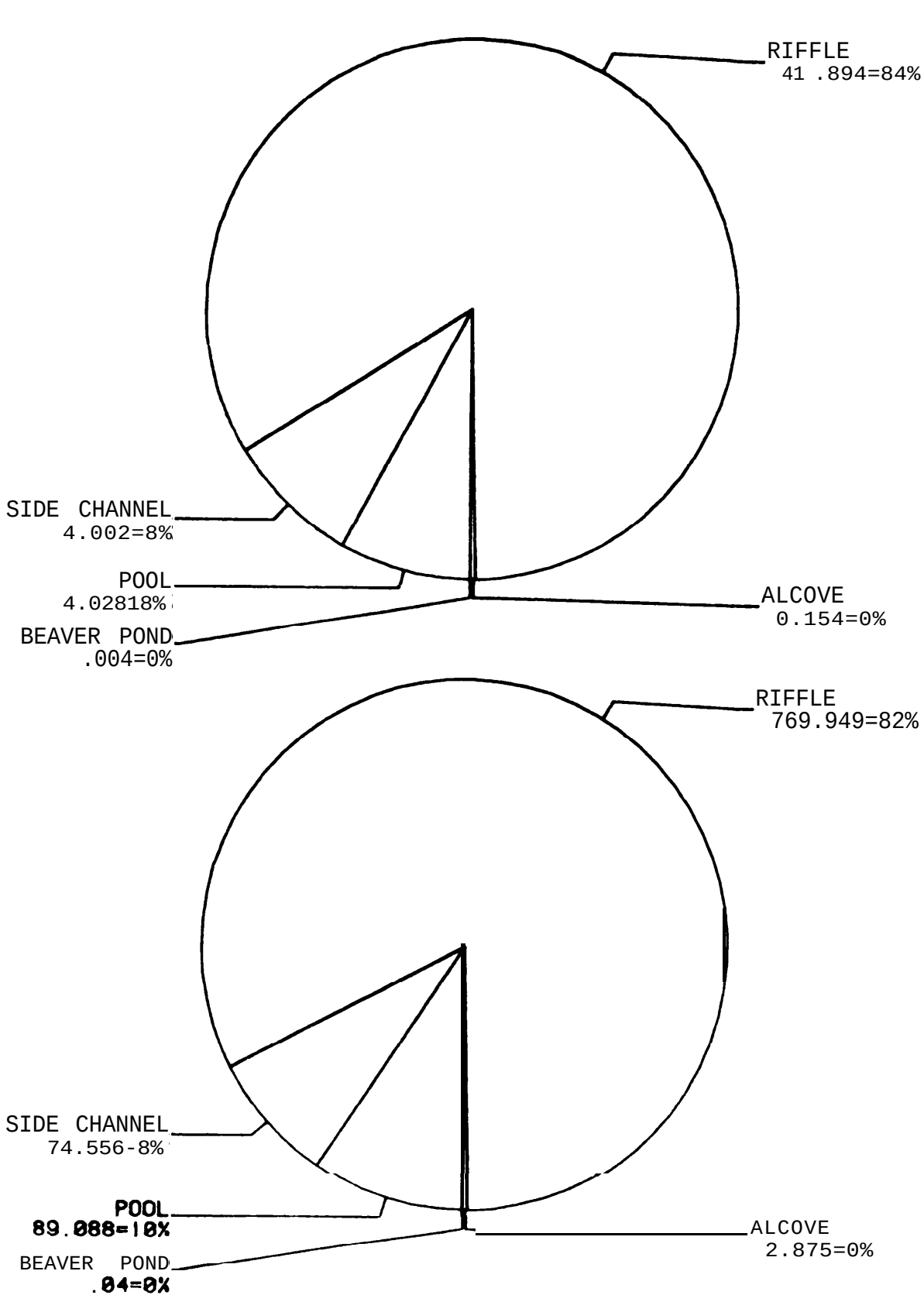
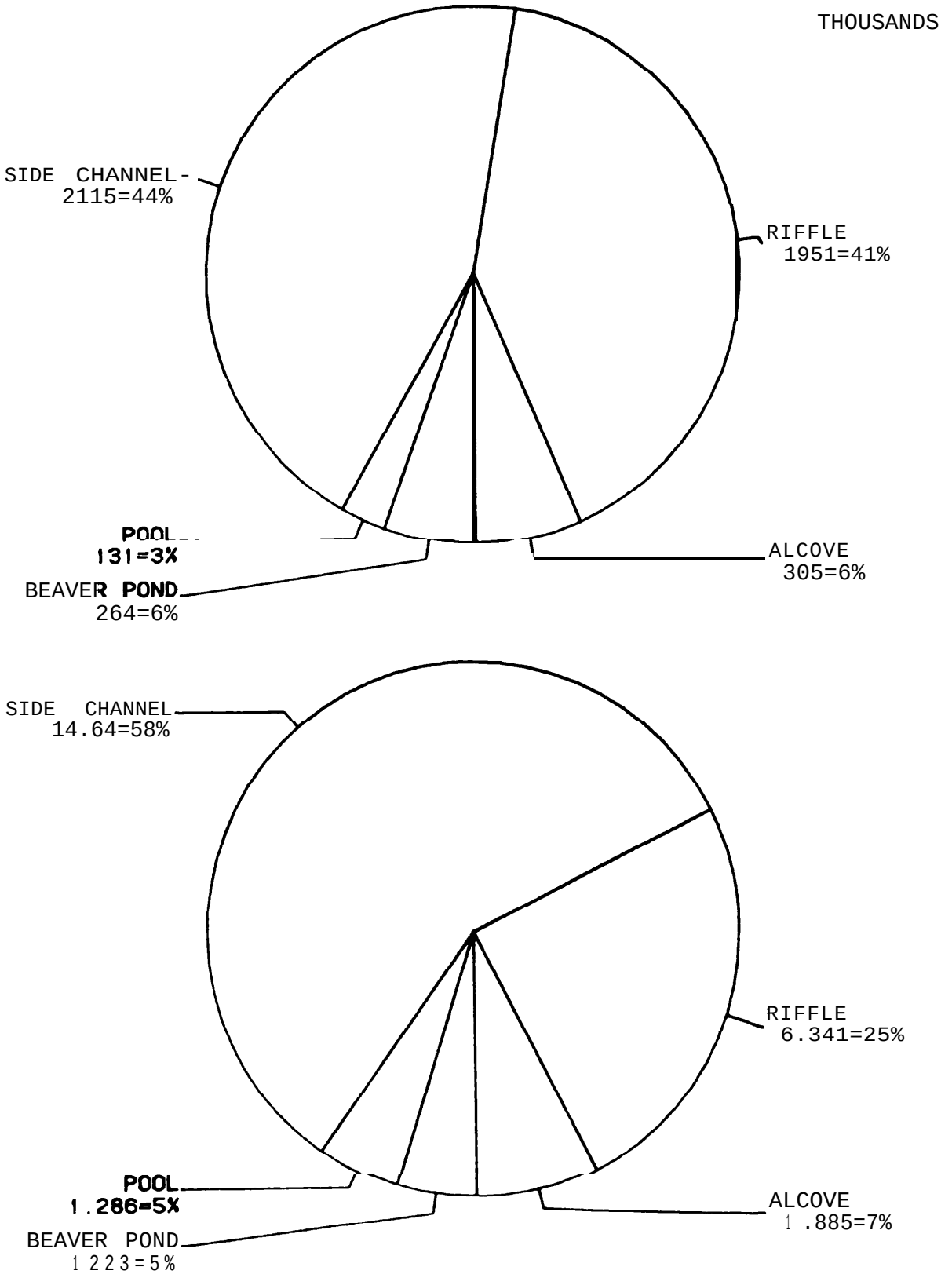


Figure 22.-Juvenile coho salmon numbers and biomass per habitat type in Fish Creek, 7982.



as side channels play a disproportionately large role in coho salmon rearing in Fish Creek.

Even in habitats preferred by coho salmon, such as alcoves or side channels, steelhead outnumbered cohc by a factor of two or threefold (Table 8). Steelhead completely dominated pools and riffles (95 and 97 percent of salmonids, respectively). The beaver pond was alnsst exclusively the domain of juvenile coho salmon.

Fish Creek Physical Habitat and Salmonid Populations--1983.

Physical Habitat--The ranking of habitats based on total surface area was unchanged on Fish Creek between 1982 and 1983. Habitats, by decreasing order of abundance, were: riffle, side channel, pool, alcove, and beaver pond. 1983 was a more abundant water year than 1982 (Table 9) and increased minimum flows in September caused an overall increase in habitat and some changes in the abundance of the 5 habitat types. TotaT habitat area was increased by 9 percent, from about 338,800 to about 370,000 m^2 (Fig. 23). The largest increase in wetted surface area, however, occurred in edge habitats (Table 10). Surface area of alcoves, side channels, and beaver ponds increased by 34, 27, and 54 percent, respectively. changes in fish populations were associates with changes in habitat area. Total area and volume for each habita type used by each species in 1983 is listed in Table 11.

Salmonid Densities and Biomass--Steelhead trout remained the most abundant salmonid in FishCreek in 1983, but there were significatn

Table 9.--Summer rainfall (inches) at North Fork Reservoir, 1982 and 1983. (Doug Cramer, PGE personal communication).

	1982	1983
June	1.2	5.2
July	1.2	4.5
August	1.7	2.5
September	4.4	1.:

Table. 10.--changes in wetted area and volume of habitat types at reference sites on Fish Creek and Wasn Creek, September 1982 and X33.

	Volume (m^3)			Area (m2:		
Habitat Type	1982	1983	% change	1932	1983	% change
Alcove	41	51	+24	152	200	+34
Riffle	116	155	+34	409	439	+7
Side Channel	60	96	+60	360	456	+27
Pool	431	471	+9	823	914	+11
Beaver Pond	36	124	+344	192	296	+54

changes in age-class strength of steelhead and in total numbers of coho and chinook salmon. Tne major changes included a 30 percent reduction (53,000 fish) (Fig. 24, Table 11) in the number of 0+ steelhead, a 323 percent increase in the number of coho salmon, and an increase from about 100 chinook in 1982 to about 1,200 in 1983 (Fig. 24, Table 11).

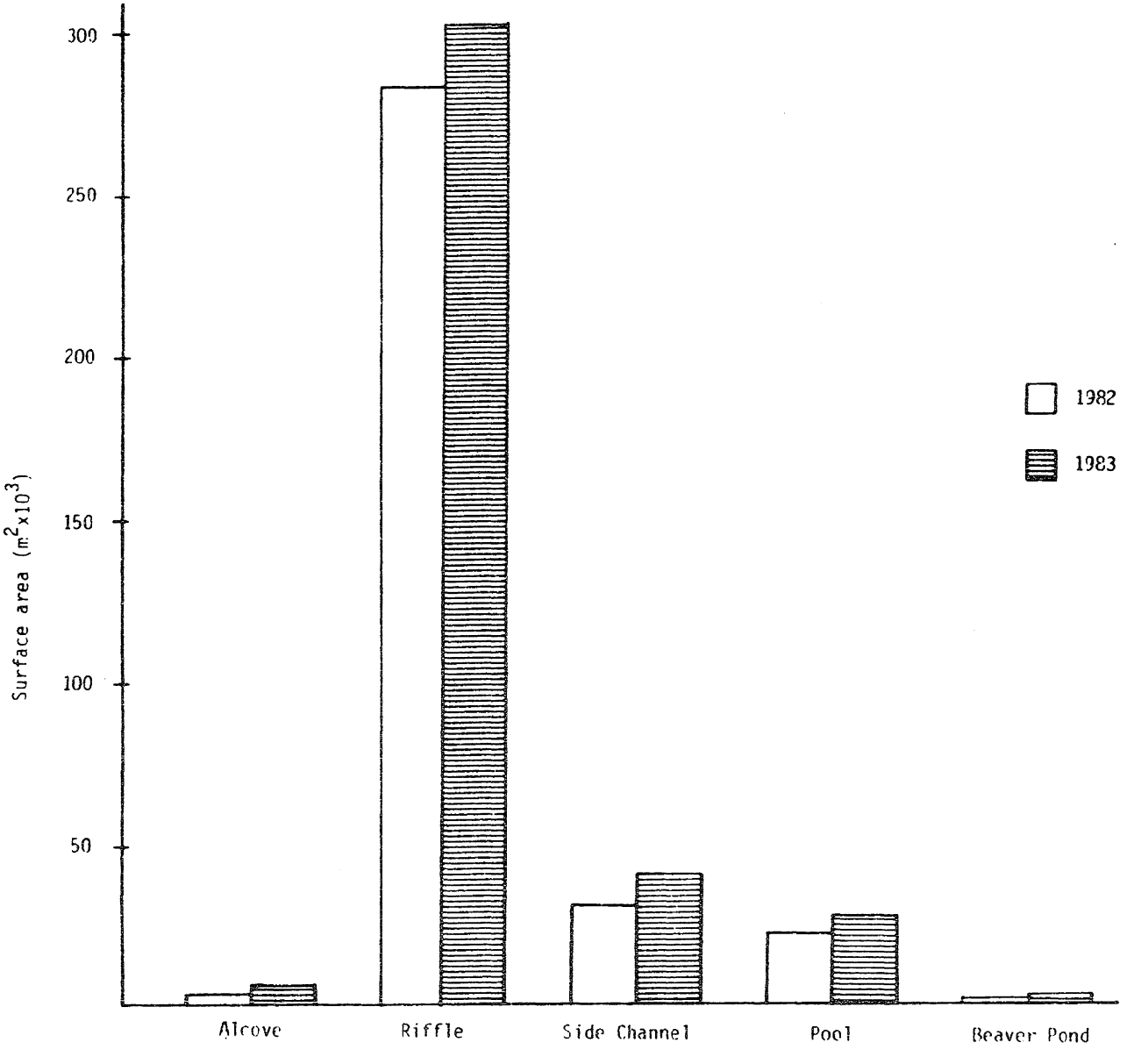


Figure 23.--Comparison of habitat surface area of Fish Creek in 1982 and 1983.

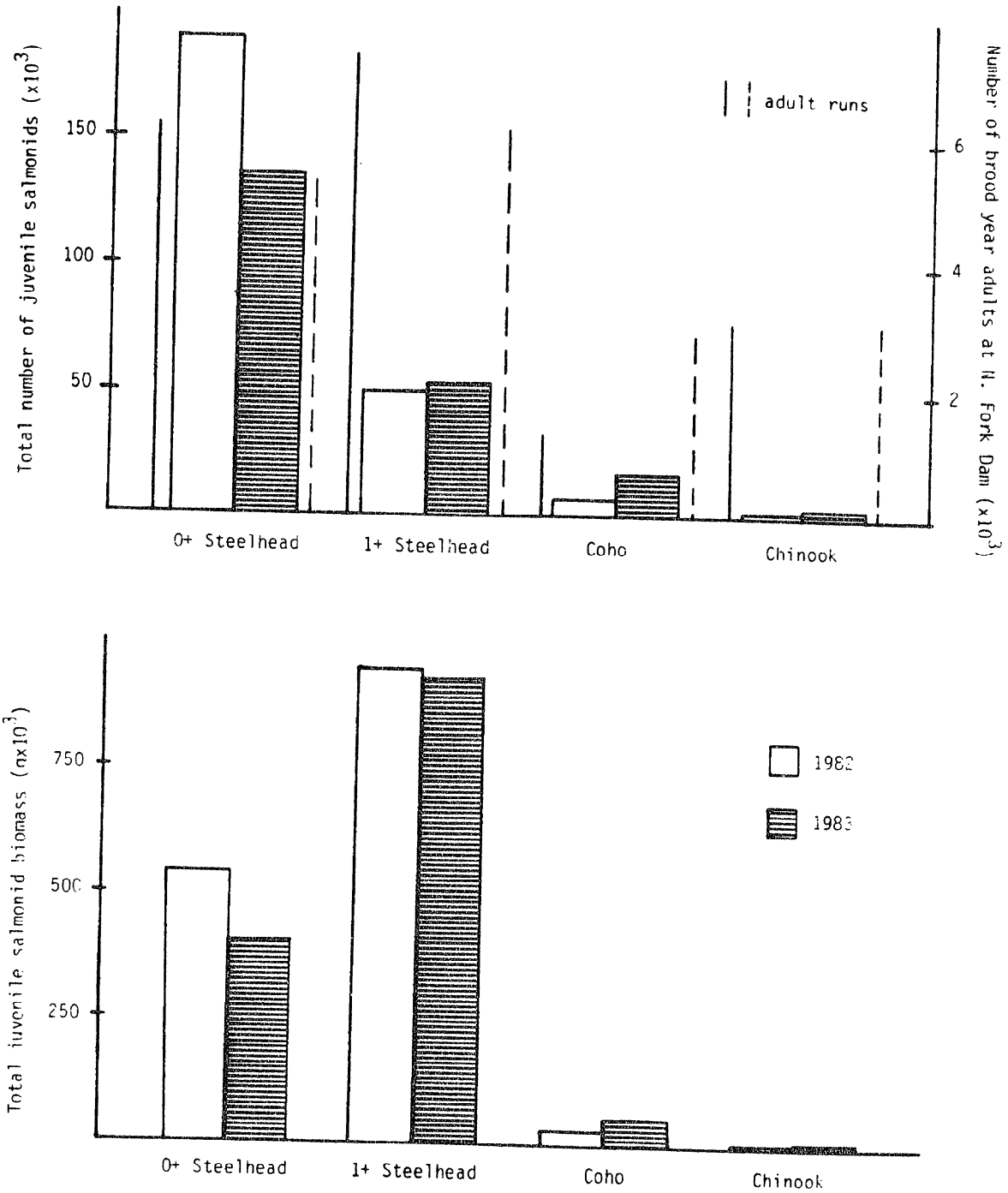


Figure 24.--Comparison of total salmonid numbers and biomass in Fish Creek for 1982 and 1983.

Table 11. Area and volume of raring hanbit types in Fish Creek used by fish their associated salmonid densities and biomass, September, 1983

SPECIES	HABITAT	AREA IN SYSTEM (m^2)	\fOtUME IN SYSTEM (m^3)	ESTIMATE F I SH MUMBER BY HABITAT	ESTIMATE FISH BIOMASS BY HABITAT	#/m^2	g/m^2	R/m3	g/m^3
Coho	Alcove	i ,272	327	433	2,120	0.30	1.90	1.30	6.50
	Riffle	83,780	29,044	3,490	19,395	0.04	0.20	0.10	0.70
	S ide channe l	15,044	4,229	a ,867	25,704	0.60	1.70	2.10	6.10
	Pool	4,214	2.017	2,284	10,510	0.50	2.50	1.10	5.20
	Beaver pond	296	124	241	675	0.80	2.30	1.90	5.40
	Total	104,606	35,741	15,315	58,404				
Chinook	Alcove	1,272	327	9	27	0.01	0.02	0.03	0.08
	Riffle	83,730	29.044	388	1,551	0.005	0.02	0.01	0.05
	Side channe l	15,044	4,229	0	0	0	0	0	0
	Pool	4,214	2,017	821	4,470	0.19	1.06	0.41	2.22
	Dearer pond	296	124	0	0	0	0	0	0
	Tota l	104,606	35,741	1,218	6,048				
0+ STHD	Alcove	4,527	1,009	1,015	2,841	0.20	0.60	1.00	2.80
	Riffle	30 1,a97	89,399	99,115	277,522	0.30	0.90	1.10	3.10
	Side channel	38,622	3,906	22,210	70,752	0.60	1.80	5.70	18.10
	Pool	24,380	12,415	3,340	30,823	0.40	1.30	0.80	2.50
	Beaver pond	296	124	4	13	0.01	--	0.03	--
	Total	369,772	106,853	131,584	381,951				
1+ STHD	Alcove	4,527	1,009	165	4,340	0.04	1.00	0.20	4.30
	Riffle	301,897	83,399	43,670	785,077	0.10	2.60	0.50	8.80
	Side channe l	38,622	3,906	3,396	57,737	0.10	1.50	0.90	14.80
	Pool	24,380	17,413	5,475	91,432	0.20	3.80	0.40	7.40
	Beaver pond	296	124	0	0	0	0	0	0
	Total	369,722	106,853	52,706	938,581				

The decrease in the population of 0+ steelhead in 1983 can be attributed to three possible factors. The adult run of steelhead over N. Fork Dam on the Clackamas was 15 percent lower in 1982-83 than in 1981-82 (Fig. 24). The reduction in parent run size for 1983 Ot progeny could have resulted in a 15 percent reduction in egg deposition and fry production in Fish Creek and account for approximately half of the observed decrease. Second, the largest decrease in numbers of rearing 0+ steelhead occurred in riffles (Fig. 25). In 1982 about 147,000 0+ steelhead were rearing in the margins of mainstem riffles of Fish Creek and Wash Creek. In 1983 only about 99,000 were estimated to be using these same habitats. It seems probable that increased minimum flows in 1983 are partially responsible for the decrease. The steep boulder riffles of the mainstem are a strenous environment for Ot steelhead and suitable living space in riffles is directly related to conditions at the margin. Lower stream flows provide more quiet water marginal habitat in riffles suitab?e for Ot steelhead, while increased flows provide more high velocity habitat for Jt fish. Third, the favored habitat for 0+ steelhead, side channels, increased by about 27 percent in 1983, but use of this habitat by coho salmon increased by more than 300 percent (Fig. 26). Since juvenile coho salmon are larger and more aggressive than 0+ steelhead, competition for space in side channels in 7983 might have reduced Ot steelhead numbers there. In total these factors could easily account for a 30 percent reduction in Ot steelhead numbers in 1983.

The pattern of habitat use by 1+ steelhead in 1983 was nearly identical to that observed in 1982. Riffle habitats favored by this age

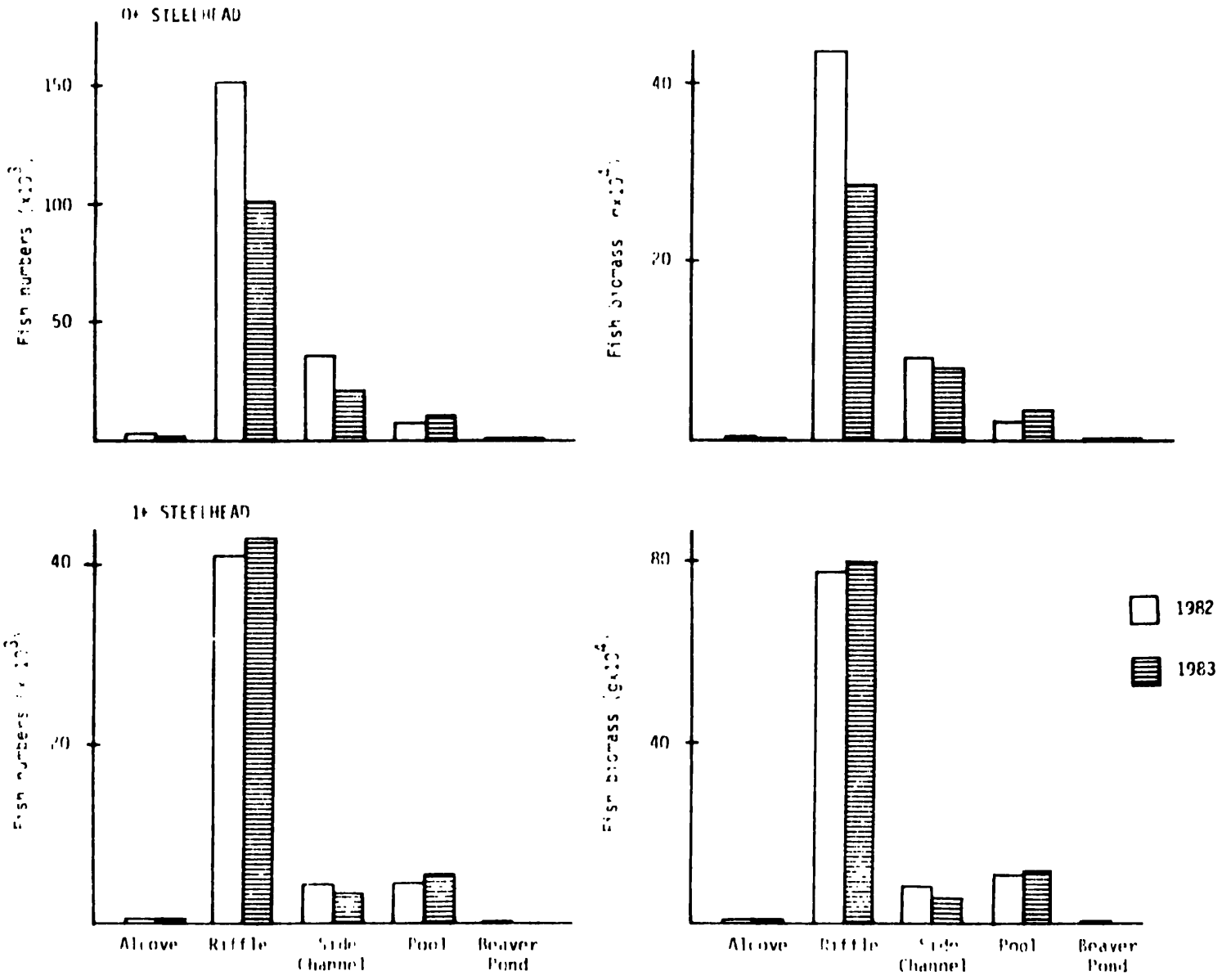


Figure 25.--Comparison of 1982 and 1983 Fish Creek 0+ and 1+ steelhead numbers and biomass in different habitats.

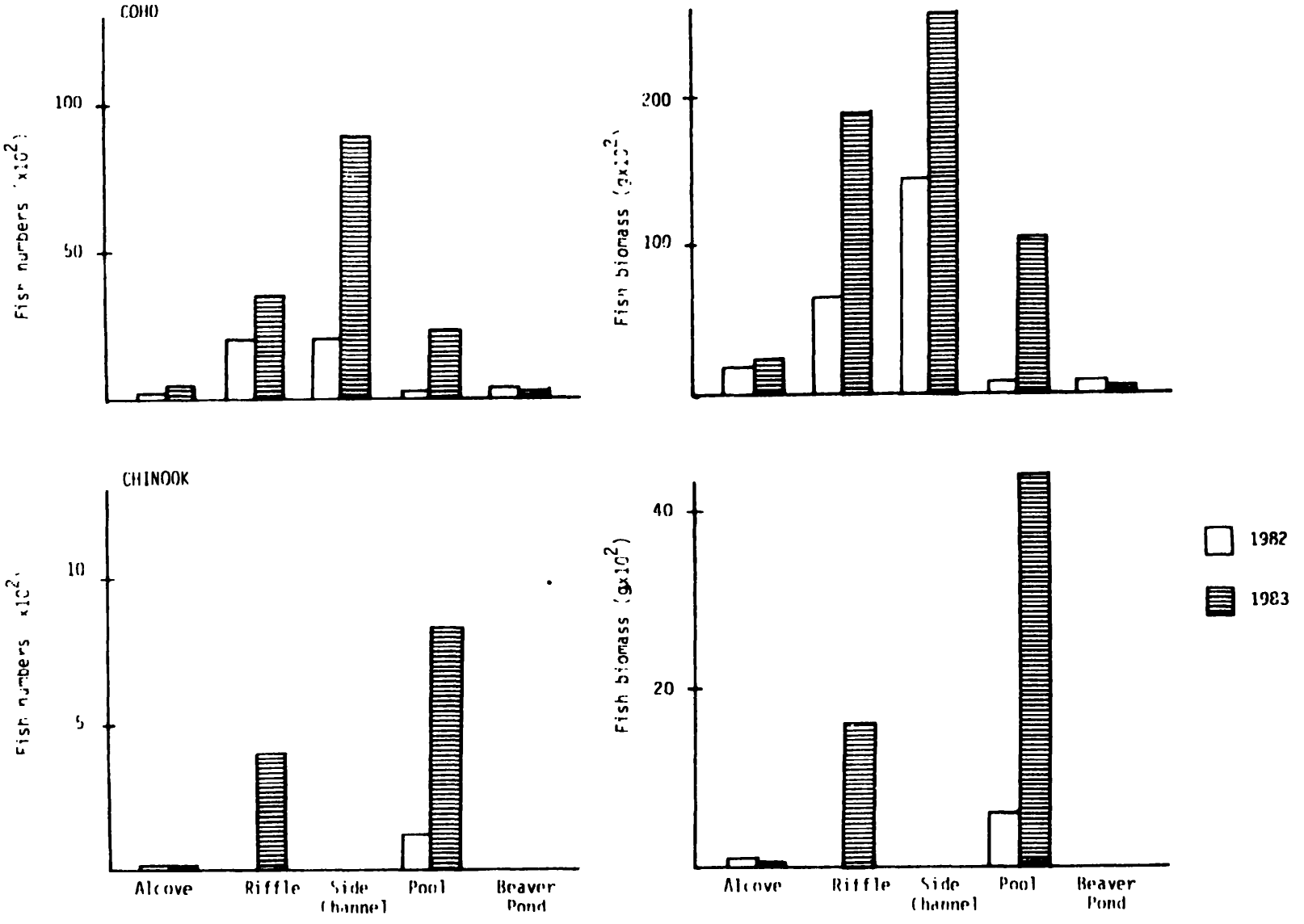


Figure 26.--Comparison of 1982 and 1983 Fish Creek juvenile coho and chinook salmon in different habitats.

group increased in area by 7 percent in 1983 and fish numbers increased by about 5 percent., In both years about 83 percent of the 1+ steelhead were rearing in riffles and 10 percent at the head of pools (Fig. 25).

Coho juveniles were far more abundant in Fish Creek in 1983 (15,000) than in 1982 (5,000). Much of the difference might be related to escapement (Fig. 24). The parent run in 1982 consisted of 1,280 coho counted over N. Fork Dam; in 1983 2,949 fish were counted over the dam. Seeding increase alone could account for more than two-thirds of the observed increase in coho, but favored rearing habitats also increased significantly. Side channels increased 27 percent in area, but the number of coho rearing in side channels increased by a factor of four. Significantly larger numbers of coho were also found in mainstem pools and riffle margins in lower Fish Creek in 1983 (Fig. 2C). It appears that as favored edge habitats (side channels, alcoves, and beaver enhanced side channels) reached carrying capacity for juvenile coho, excess fish moved into less favored riffle margins and pools where few fish were found in 1982.

Few chinook reared in Fish Creek in 1982 but a large parent run resulted in more than 1,200 rearing there in 1983 (Fig. 24 and 25). Higher minimum flows in 1983 might also have induced more chinook to remain in Fish Creek rather than migrate to the Clackamas. Favored habitats for chinook were large mainstem pools in lower Fish Creek.

Salmonid Utilization of Different Habitats in Fish Creek, 1982-83.

Riffle habitats--Salmonid numbers in riffles are dominated by 0+ steelhead (77 percent in 1982 and 68 percent in 1983) and two-thirds of

the salmonid biomass consisted of 1+ steelhead trout (Fig. 27). The main difference in salmonid utilization of riffles between 1982 and 1983 was the decrease of 0+ steelhead and increase in coho and chinook salmon.

Pool Habitats--Steelhead trout dominate both biomass and numbers of salmonids in the pools of Fish Creek (Fig. 27). In 1982 0+ steelhead accounted for two-thirds of salmonid numbers but decreased to one-half of the total in 1983. The main difference was the increase in number of coho and chinook salmon juveniles and 1+ steelhead juveniles in 1983. Nearly 80 percent of the salmonid biomass in 1982 was 1+ steelhead (Fig. 28) and in 1983 1+ steelhead accounted for two-thirds of the salmonid biomass.

Side Channels--The area of side channels was larger in 1983. Coho salmon responded to this habitat expansion in terms of absolute numbers as well as making up a greater proportion of the salmonid population rearing in side channels (Fig. 29). This habitat type was still dominated by Ot steelhead in 1983 (64 percent compared to 84 percent in 1982). On wet summers such as 1983, when the side channels contain water throughout the dry season, rearing coho are selecting this edge habitat. Biomass of the salmonids in side channels reflects the increase in coho salmon, but side channels are still dominated by about equal biomasses of l+ and O+ steelhead trout.

Alcoves--The edge pools formed around boulders, wood debris and root wads also experienced proportional increases in coho numbers and biomass in 1983. Coho represented 27 percent of the salmonids in alcoves in 1983 (Fig. 30) and Ot steelhead fell from 79 percent in 1982 to 63 percent in

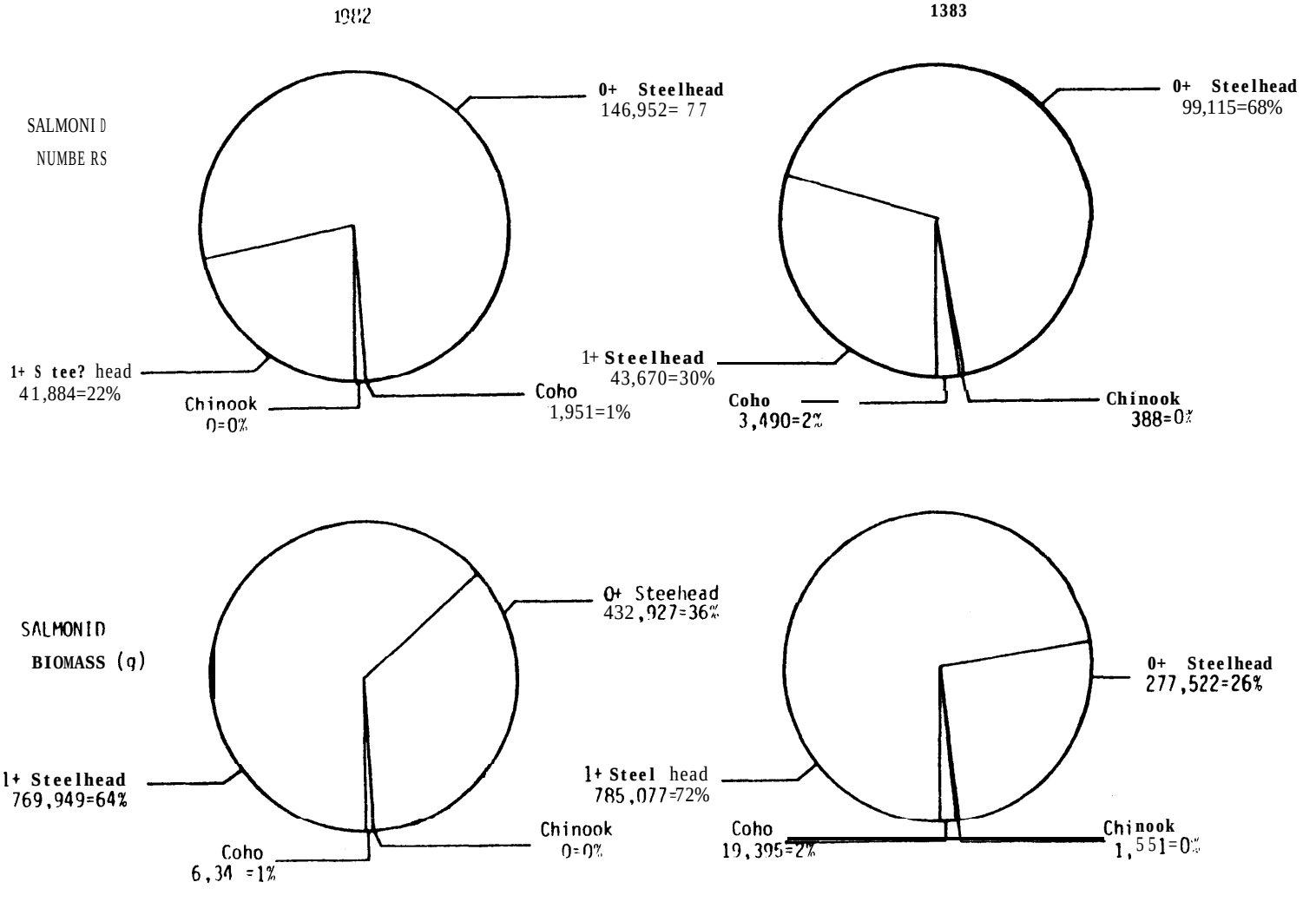


Figure 27.--Partitioning of salmonid species and age class numbers and biomass in riffle habitats.

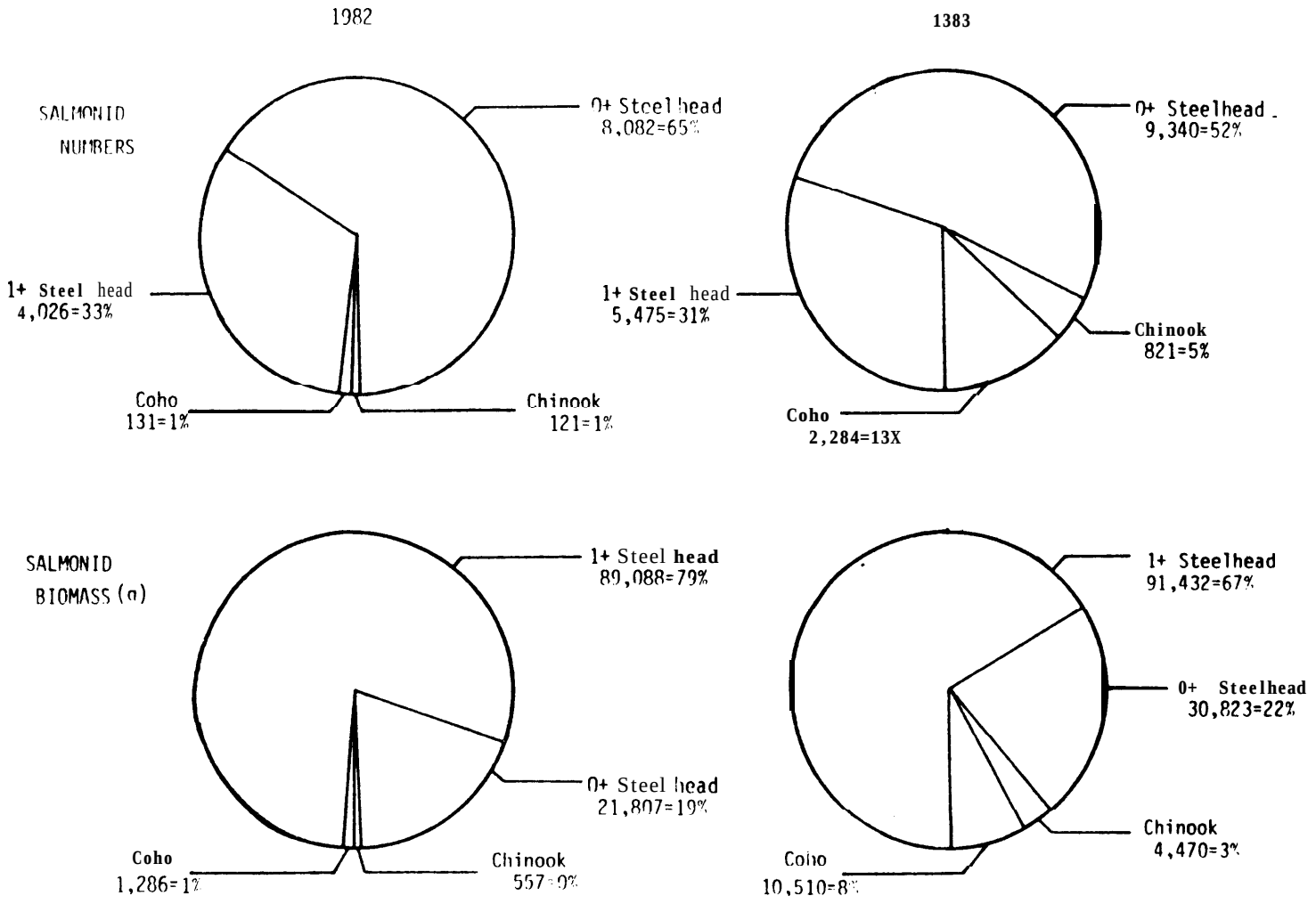


Figure 28.--Partitioning of salmonid species and age class numbers and biomass in pool habitats.

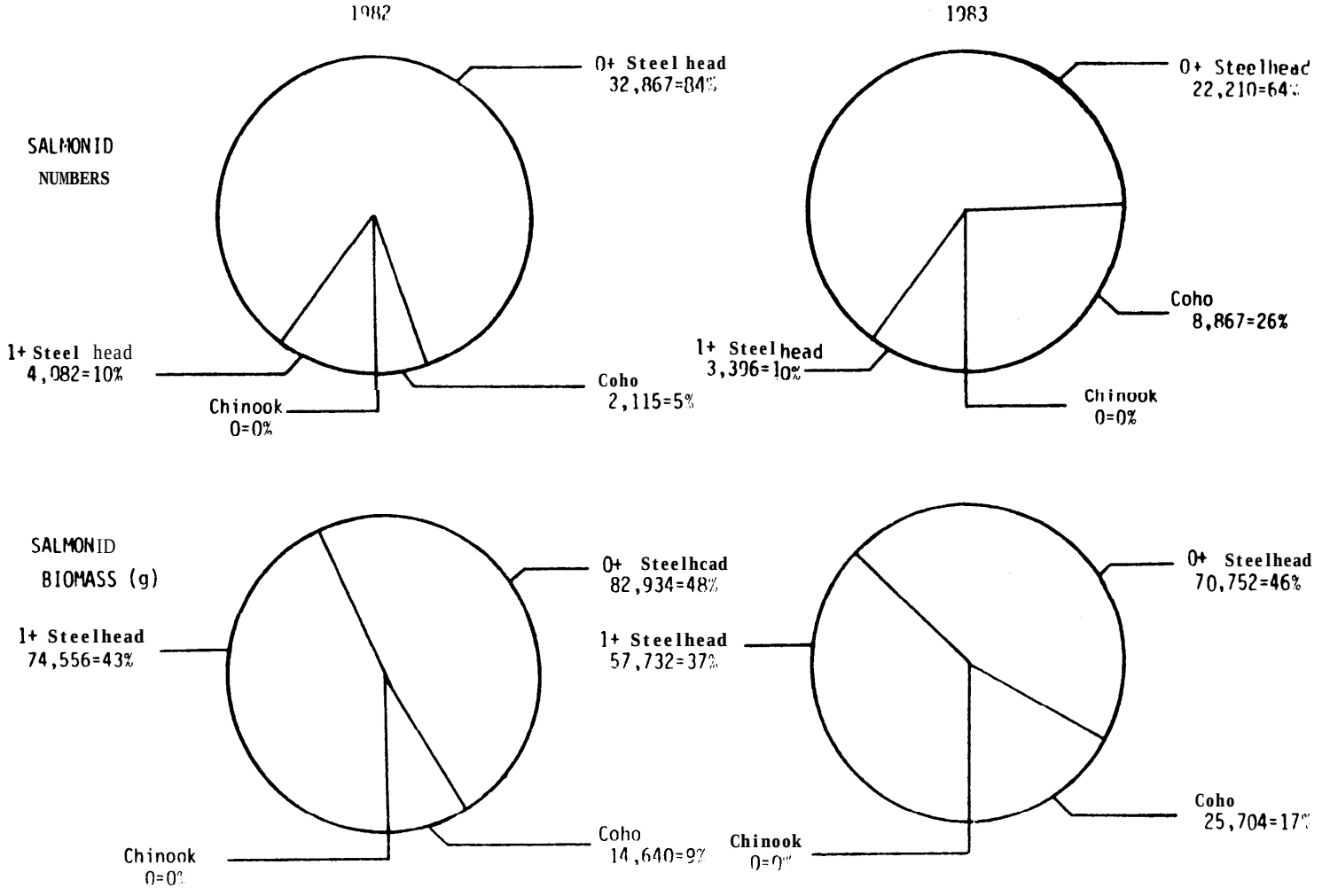


Figure 29.--Partitioning of salmonid species and age class numbers and biomass in side channel habitats.

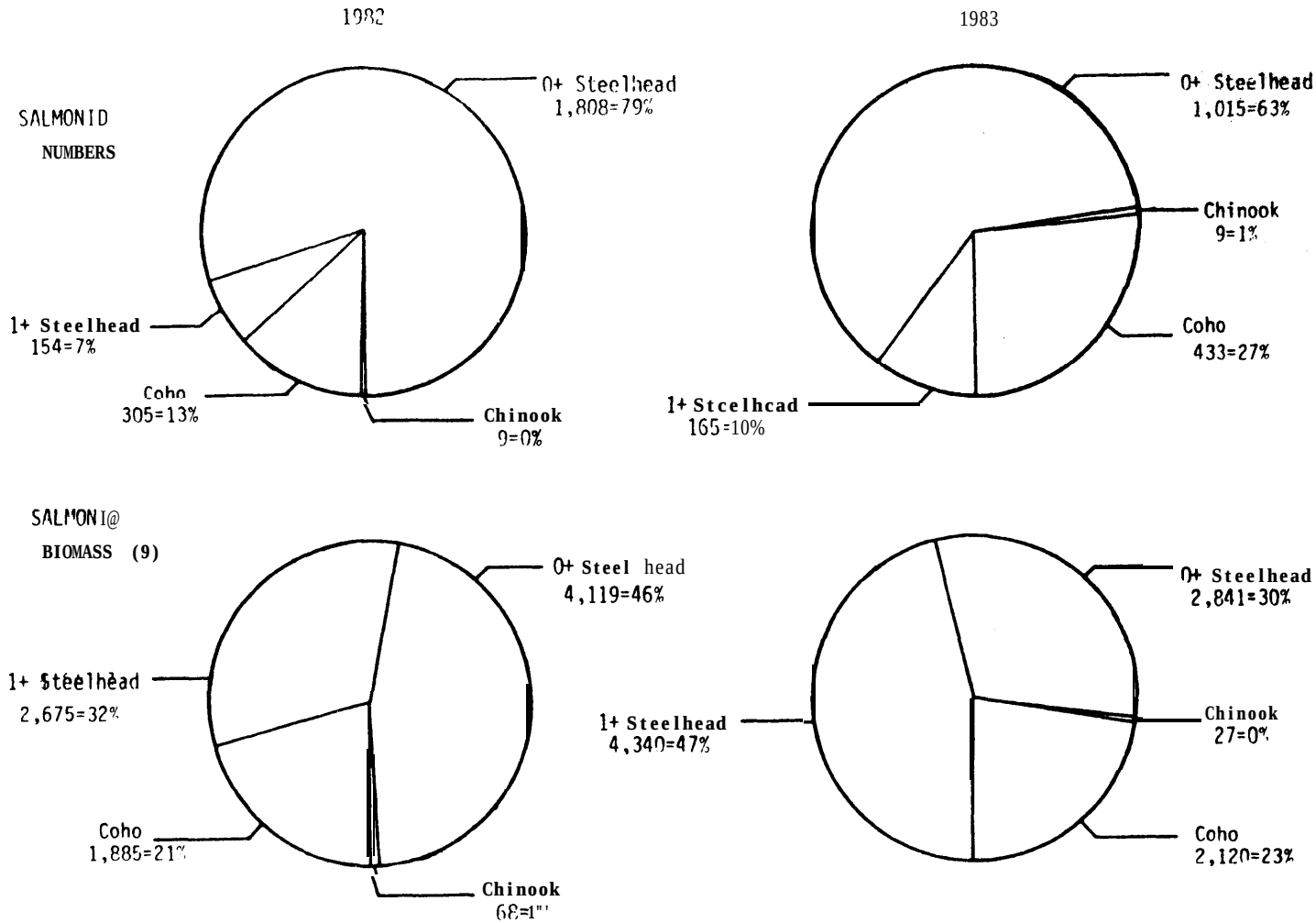


Figure 30.--Partitioning of salmonid species and age class numbers and biomass in alcove habitats.

1983. Age 1+ steelhead made up 32 percent of the biomass in alcoves in 1982 and 47 percent in 1983. The biomass of coho salmon in alcoves did not change significantly across years (Fig. 30).

Beaver pond--The beaver ponded side channel continued to be the domain of juvenile coho salmon in 1983. Over 96 percent of salmonid numbers and biomass was composed of coho salmon juveniles (Fig. 31). While the habitat area expanded, the total numbers decreased slightly from 1982 population estimates.

In summary we saw very little shift in the utilization of habitat types by different ages and species of salmonids. Proportions of a given species changed within a habitat more on the basis of absolute increases or decreases in population size rather than a major shift in habitat preference. Coho salmon junveniles increased in numbers and occupied quiet water in edge habitats.

Significance of N. Fork Reservoir to Rearing Salmonids.

When planning habitat improvements in a tributary of a major river system like the Clackamas, it is important to know the availability of off-site rearing habitat. For example, spawning habitat in a tributary like Fish Creek might be more than adequate to seed available rearing areas in the stream. If this is true, development of additional spawning habitat would not increase smolt production in Fish Creek, but might help to fill underseeded mainstem or reservoir habitats in the Clackamas River downstream. The reservoir habitats in particular provide a large potential rearing area for juvenile chinook and coho salmon that prefer

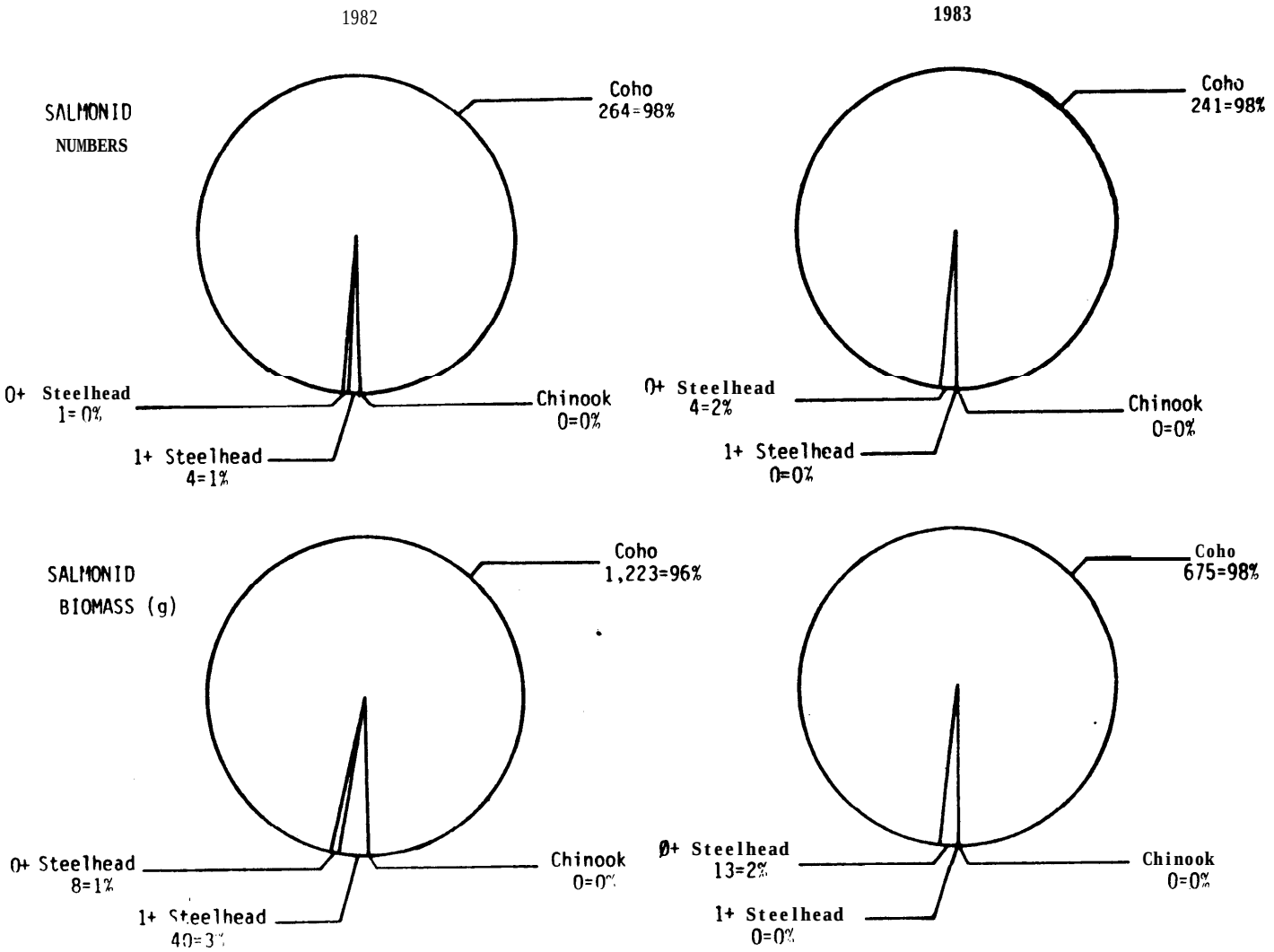


Figure 31. --Partitioning of salmonid species and age class numbers and biomass in the beaver pond habitat.

quiet water habitats. If habitat in N. Fork Reservoir is not fully occupied by rearing coho and chinook, then development of additional spawning habitat in Fish Creek might be justified. Excess juvenile salmonids spawned in Fish Creek would be forced through population pressure to emigrate downstream to rearing areas in the Clackamas River and N. Fork Reservoir.

From 1962 to 1965 the Fish Commission of Oregon studied the seasonal distribution and abundance of juvenile salmonids in N. Fork Reservoir. North Fork is the uppermost of a three dam complex on the Clackamas River. It is 46 km upstream from the confluence of the Clackamas and the Willamette rivers. The dam has a head of 41 m and forms a reservoir 6.5 km long with a surface area of 134 ha and a storage capacity of 23 million m^3. The Clackamas River and one small tributary flow into the reservoir.

The following observations and conclusions are based on the Fish Commission report (Korn et al. 1967). Gillnets, traps, and SCUBA gear were used as sampling equipment in the study. Sampling was conducted at all months of the year and at depths from the surface to 23 meters. Rough estimates of abundance were made by releasing known numbers of marked fish into the reservoir and then assessing the marked to unmarked ratio of the subsequent catch.

Juvenile salmonids were caught in the reservoir in every month that the traps were fished (Table 12), and particularly large numbers of 1961 and 1962-brood coho were caught throughout each of the first two run-years. Recovery in the traps of less than 5 percent of 2,015 coho

Table 12. Catches of chinook and coho salmon and rainbow-steelhead trout in floating traps by month and run-year, 1/ North Fork Reservoir, 1962-65.

Month	Species and run year: Chinook			Coho			Rainbow-steelhead 2/		
	1962 63	1963 64	1964 65	1962 63	1963 64	1964 65 3/	1962 63	1963 64	1964 65
July	143	48	--41	1,384	538	--	332	61	--
August	74	0	227	135	9	172	603	287	1,037
September	132	a	114	1,943	163	300	605	172	1,071
October	25	17	--	287	1,106	I-	240	265	I-
November	69	88	--	2,642	7,736	--	283	371	-m
December	37	1	--	2,160	526	--	320	111	--
January	11	26	41	494	400	33	95	30	165
February	109	15	141	5,888	607	205	775	37	374
March	16	26	108	1,094	696	406	134	46	391
April	a	47	92	1,796	2,829	1,052	322	421	918
May	18	23	21	2,476	1,162	1,587	678	320	797
June	58	52	0	246	266	39	58	49	44
Total	700	351	744	20,545	16,038	3,794	4,445	2,170	4,797

1/ A run-year extends from July of one year through June of the next. Emigration of a given age class of juvenile salmon from North Fork generally occurs on a run-year basis, but steelhead emigrate only in the spring.

2/ Fish thought to be steelhead, but may include rainbow trout.

3/ Catches of coho from March-June 1965 may include unmarked hatchery fish.

4/ A dash (--) means the traps were not fished that month.

tagged between February and June 1963 and 4,884 coho tagged from July 1963 to June 1964 indicated the majority of the 20,545 and 16,038 fish caught in each of these run-years were part of much larger populations. It was not possible to use these data to make definitive estimates of the numbers present due to the instability of the population resulting from emigration via the spillway and the extended period of tagging, but it is evident that large numbers of coho resided in the reservoir. The percentages of tagged rainbow-steelhead and chinook salmon recovered in the traps were also low. Good numbers of the former were probably present in the reservoir each year, but few chinook were found.

Observations from a boat and by the use of SCUBA showed chinook, coho, and rainbow-steelhead fry inhabiting the surface waters of North Fork Reservoir in the late winter, spring, and early summer of each year. From May to July 1963, more than 5,000 yearling and fry coho, *fry* chinook, and fry rainbow-steelhead were captured with a seine and dip net. All fish were taken from the surface to 4.5 m of depth. Observations with SCUBA showed that fry salmonids generally were not found below a depth of 4.5 m.

Additional information on depth distribution at North Fork was obtained by counting fish at night while using SCUBA gear to swim 46 meter-long transects near the shoreline and on the bottom at depths of 4.5, 9, and 15 m, In all seasons except the winter, the majority of the coho counted were near the shoreline. In the winter, the counts were evenly distributed between that location and depths of 4.5 and 9 m. Few, if any, fish were seen at 15 m in any season.

The total number of coho in the reservoir was estimated at 145,700 in September of 1962. The parent run in 1961-62 was about 2,200 fish. Surface area of the reservoir is approximately 133.6 hectares. Density of coho in September 1962 was about 0.1 fish/m2 throughout the reservoir and about 0.5 fish/m^2 in the favored edge habitats within 15 m of shore. The latter figure is close to coho densities observed in 10.8

2,900 fish, and might indicate that little excess rearing habitat for coho exists in the reservoir if parent runs exceeds about 2,500 fish. If these assumptions hold, then rearing habitat enhancement projects in streams of the upper Clackamas basin are probably the most promising means of increasing coho runs in the system, assuming adequate escapement to seed available habitat. Numbers of juvenile chinook in the reservoir were low, indicating some potential for increased rearing of this species.

Amount of Large Woody Debris in Mainstem Fish Creek.

In January 1984 the number of large downed trees and board feet of wood in downed trees was determined for the lower 8.0 km of Fish Creek. The purposes of this survey were: 1) to estimate total amounts of large wood in the stream channel and adjacent flood channels; 2) to determine what percentage of wood entered the stream via the Christmas 1983 ice and wind storm (ice storm Dec. 25-26; wind storm 26-29); and 3) determine the positive and negative effects of this woody debris on fish habitat.

We measured 142 pieces of large organic debris from downed trees which ranged in length between 3 and 35 m and 0.1 - 1.5 m in diameter. The wood averaged about 15 m long and 0.4 m in diameter. If the debris was evenly distributed, it would be about one piece per 56 m. About 80 percent of the total number was found in 21 debris clumps within blowdown areas, or an average of one debris clump every 400 m. The total volume of wood in the stream was 130,000 bd ft., with approximately 17 percent of the wood in flood channel areas.

Many pieces of debris and connected root wads were trapping gravels on the upstream side and at the tail of scour pools just downstream of the wood. Most of the pieces were rotated to a 30-40' angle to the bank. The recent blowdown debris was in the process of stablizing and readjusting to winter storm flows at the time the survey was conducted. Total debris in Fish Creek-Wash Creek will be estimated this summer and related to pool creation and gravel entrapment.

The Christmas ice and wind storm accounted for about 62 percent of the wood in the survey reaches or about 80,600 bd. ft. The remaining 38 percent was in the stream before the fall of 1983.

The Estacada R. D. has estimated 20-25 million board feet were blown down in Fish Creek Basin. The blowdown in the stream represents less than one half of one percent (0.5 percent) of the total volume blown down. We recommend leaving this small additional volume and incorporating the downed trees into our fish habitat study design.

Effects of Habitat Improvements on Rearing Habitat.

Boulder Berms--The twenty-one boulder berms constructed on Fish Creek and Wash Creek made significant changes in the overall habitat structure of the stream (Fig. 32). The purpose of the berms was to recruit bed load gravels and ultimately enhance spawning habitat for anadromous salmonids. The Mediate changes after construction, however, were increases in pool habitat and decreases in substrate particle size in proximity to the berms. Each berm that spanned the stream functioned as a low dam that created pool habitat. A total of 18 berms created pool habitat totaling 5,763 m^2 and 2644 m^3 (Table 13). Average depth of pools at low flow was 0.43 m. Construction of the berms increased pool habitat for the entire anadromous fish reach of Fish Creek by about 24 percent and reduced total riffle habitat by about 2 percent (Table 14). Areas of side channels and alcoves were not significantly affected by berm construction.

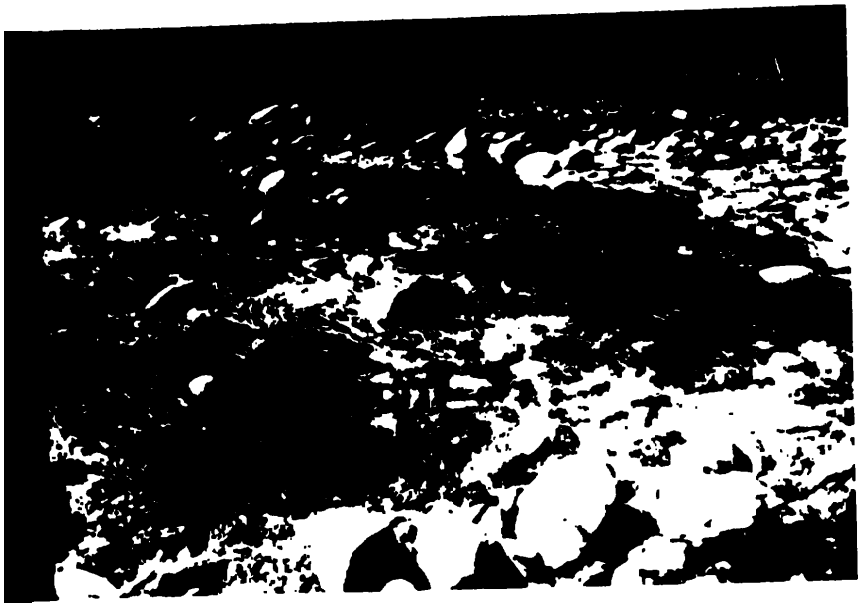
The increased pool area and volume created by the berms will slowly revert to riffle habitat as the pools fill with bedload gravels. The loss of pool habitat upstream from each berm will be partially compensated by probable development of plunge pools at the downstream face of berms. Also, additional spawning habitat will be created as upstream pools fill with gravel.

Berm construction also created significant changes in substrate composition. The area of streambed within the wetted perimeter around each berm site was dearmored of boulders and rubble during construction. The large particles were used to build the berms, and after completion of

Before

After

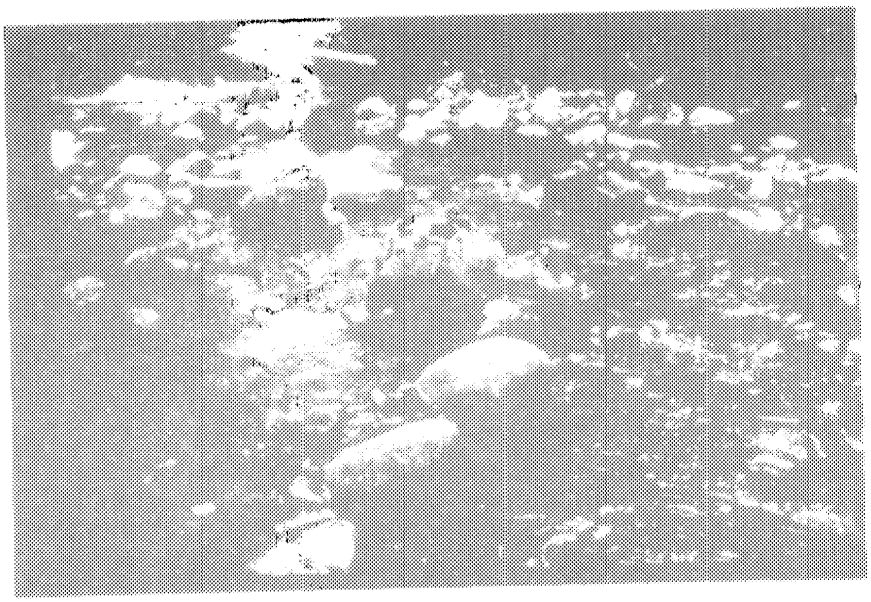
Figure 32.--Boulder berm sites on Fish Creek before and one month after construction.



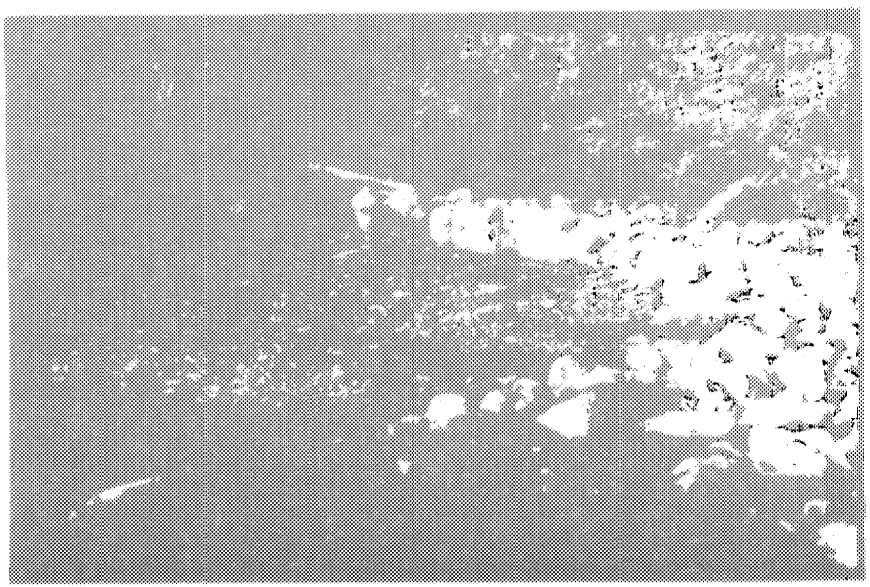
Before

After

Figure 32. (continued)



Before



After

Figure 32.--(continued). Boulder berm sites on Wash Creek before and one month after construction.

Table 13.--Changes in riffle and pool habitat resulting from construction of rock berms on Fish Creek and Wash Creek, 1983.

Site	Number Berms	Average pool depth (m)	Total pool area increase (m^2)	Pool volume increase (m^3)	Volume increase per pool (m^3)
1) Wash	3	.38	385	146	49
2) Suspender reach (a)	7	.58	2,366	1,372	196
3) Suspender reach (b)					
(Upper)	3	.40	1,046	418	139
(Lower)	5	.36	1,966	708	142
4) Bridge	3	0	0	0	--
Totals	21		5,763	2,643	

Table 14. Habitat area and volume in stream channel accessible to anadromous fish before and after construction of 21 rock berms on Fish Creek and Wash Creek, 1983.

	Before		After		% Change	
Habitat type	Area m2	Volume m3	Area m2	Volume m3	Area	Volume
Riffle	301,897	89,399	296,134	87,692	-2	2
Pool	24,280	12,415	30,143	15,059	+24	+2l

the berms underlying gravel was exposed (Table 15). Gravel substrate increased a total of 1,381 m^2 within the wetted perimeter, but no increase in spawning area was noted. The exposed gravels were primarily in the bottom of pools where depth and velocity characteristics would preclude spawning

Off-channel Development--A small beaver pond on a side channel of Fish Creek at km 3 is the most productive habitat (per area and volume) for juvenile coho salmon in the system. The off-channel pond, developed in 1983 as a coho rearing area, drains into the beaver pond and shares many of its productive characteristics. The off-channel pond historically contained water in winter and spring but was dry in summer and fall. The pond was used heavily by beavers during the wet season. Periodic beaver use, coupled with an abundance of large and small organic debris from beaver activity and salvage logging provide the pond with a rich supply of nutrients. The developed off-channel pond with its perennial water source more closely resembles a beaver pond than any other habitat type in Fish Creek basin (Fig. 33) and should be as productive for coho rearing.

The developed off-channel pond has added 4,600 m^2 of "beaver pond" habitat to lower Fish Creek, a 15 fold increase over natural levels. The increase in volume of 3,600 m^3 is even greater--a 29 fold increase. If the pond produces coho at the same rate as the natural beaver pond, about 7,200 juvenile coho could be accomodated in summer and a smolt output of about 5,760 fish might be expected. Based on observations of wild coho abundance in 1982 and 1983, the pond might increase smolt output from Fish Creek by 60 to 190 percent.

Table 15. Changes in quantity of streambed gravels resulting from construction of boulder berms on Fish Creek and Wash Creek, 1983. No increase in spawnable gravels was noted.

Site	Number Berms	Substrate area affected (m^2)	Total increase in gravel (m^2)	Gravel increase per berm (m2)
1) Wash	3	259	115	38
2) Suspender reach (a)	7	744	342	49
3) Suspender reach (b)	8	2,250	817	102
4) Bridge	3	357	107	36
Totals	21	3,610	1,381	x = 56

Figure 33.--Off-channel rearing pond covers 0.5 hectare and simulates a large beaver pond.

Spawning habitat in the pond's two inlets should eventually be sufficient to naturally seed the pond with coho fry. A minimum of 20 adult female coho can be accomodated on spawning areas in the inlets if some additional spawning area enhancement is done in the south inlet. Twenty females should produce about 60,000 eggs, 18,000 fry, or 4,000+ smolts--enough to utilize much of the available habitat in the pond.

For the first 3-4 years of operation an effort will have to be made to seed the pond artifically by collecting coho fry from Fish Creek and transporting them to the pond. Coho that begin their smolt migration from the pond should home back to pond inlet streams as adults. Once this pattern is established the pond should be seeded naturally each year.

When development of the pond was completed in the fall of 1983, 150 juvenile coho were captured by electrofishing in Fish Creek tnd introduced to the pond. The fish averaged 77.4 mm in length and 5.2 g in weight. The survival and growth rates of these fish will be monitored as they leave the pond as smolts in the spring.

Spawning Habitat in Suspender limber Sale.

The reach of stream (1 km) adjacent to Suspender Timber Sale contains about 110 m^2 of spawning gravel (8 percent of system total) suitable for use by anadrornous salmonids. These gravels are used primarily by chinook salmon, and up to 14 percent of total chinook spawning in the system has been observed to occur here (Table 16). Steelhead have also been observed to use these gravels. Construction of rock berms in the

area in the summer of 1983 has increased pool habitat in the reach and a subsequent increase in spawning habitat is expected in the next few years.

Table 16. Chinook salmon adults, redds, and spawning gravel observed in Suspender Timber Sale reach, 1981-83.

	1981	Percent of total Fish Cr.	1982	Percent of total Fish Cr.	1983	Percent of total Fish Cr.
Chinook redds	2	6	12	14	1	9
Adult chinook	1	3	5	14	1	4
Spawning Gravel [m^2]	110	8	110	8	110	8

Rearing Habitat in Suspender Timber Sale.

The kinds and proportions of salmonid rearing habitat available within the Suspender Timber Sale are representative of habitats available within the entire Fish Creek Basin accessible to anadromous fish. In 1982 riffles represented 87 percent of the stream area within the sale boundaries and 83 percent of the total stream area (Table 17). Pools represented 9 percent of the area within the sale and 7 percent throughout the basin. While the area occupied by riffles and pools were representative of the entire stream system, the volumes of water within

Table 17.--Fish rearing habitat available in the Suspender Timber Sale (500 m of stream) relative to the total Fish Creek system.

Habitat	Stream Area Surveyed (m^2)	%	Stream Volume Surveyed (m^3)	%	Total Stream Area (m^2)	%	Total Stream Volume (m^3)	%
Alcove	96	1	11	0.4	3,379	1	814	1
Riffle	8,656	87	1,940	72.8	282,147	83	66,716	82
Sidechannel	310	3	18	0.7	30,411	9	2,441	3
Pool	933	9	697	26.1	21,964	7	11,390	14
Total	9,995		2,666		337,901		81,361	

the sale areas were different; the riffles were shallower and the pools larger within the sale. Pools within the sale account for 26 percent of the sale area volume compared to pools accounting for 14 percent for the entire system. Side channel and alcove habitats are scarce within the sale area.

These habitat characteristics translate into more 1+ steelhead trout juveniles in response to the pools. In general, the Suspender Sale area is representative of the total stream system. Because the sale area is

in a more constricted, canyon-like area, side channels are not large and are dependent on large boulders and large woody debris near the stream margins for small side channels and alcoves. The sale area has very few juvenile coho salmon rearing in it and is on the upper limits of the coho salmon rearing range (Fig. 18). The habitat because of the side-slope constriction exhibits high velocities in the riffles and relatively fast-moving water in the scour pools.

Construction of 15 berms in the Suspender Timber Sale reach in 1983 significantly changed the structure of the habitat. The major change occurred in the ratio of riffle to pool habitat in this 0.5 km reach. Riffle:pool ratio before construction was about 9:1, and after construction about 1:2 (Table 18). Pools created by the berms are shallow, averaging about 0.5 m in depth, and will probably fill with bedload gravels within a few years. The gradual transition from pool to gravel riffle will shift habitat use from dominantly rearing to a balance between rearing and spawning.

Changes in fish populations associated with increased pool habitat can not yet be assessed. An analysis of fish populations was made in the area prior to construction of berms, but comparative post-construction biological data will not be collected until the summer of 1984.

Table 18. Changes in riffle and pool habitat due to rock berm construction in a 0.5 km reach of Fish Creek within Suspender Timber sale, 1982-83.

Habitat type	Before berm construction	After berm construction	% change
riffle	8,656 m^2	3,278m^2	-62
pool	933 m^2	6,311 m^2	+676
riffle/pool ratio	9:l	1:2	

Summary of Expenditures (Fish/Wash), FY 83

Expense	BPA	KV
Personnel		
GS-14 @ 180/d	--	2,700
GS-13 @ 168/d	--	2,520
GS-08 @ 84/d	3,360	1,090
GS-06 @ 64/d	2,560	960
GS-05 @ 57/d	8,270	1,400
Travel	2,200	1,340
Per Diem	9,700	3,600
Supplies	4,000	2,500
Totals	30,090	16,110

SUMMARY AND CONCLUSIONS

1. Steelhead trout remained the most abundant salmonid in Fish Creek in 1983, but there were significant changes from 1982 to 1983 in age-class strength of steelhead and in total numbers of coho and chinook salmon. Major changes included a 30 percent reduction (58,000 fish) in the number of 0+ steelhead, a 320 percent increase in the number of coho salmon (from 5,000 to 15,000), and an increase from about 100 chinook in 1982 to about 1,200 in 1983.

2. 1983 was an abundant water year and high summer streamflow provided an approximate 30 percent increase in favored edge habitats (alcoves, side channels) used by rearing coho and 0+ steelhead.

3. Gravel quantity and quality in Fish Creek appears adequate to seed available rearing habitats with juvenile steelhead and coho.

4. The addition of 21 boulder berms to Fish Creek and Wash Creek in the summer of 1983 made significant changes in the overall habitat structure of the stream. The berms increased pool habitat within the range of anadromous fish by 24 percent (5,763 m^2 and 2,644 m^3) and reduced riffle habitat by about 2 percent.

5. Development of an off-channel rearing pond has added 4,600 m^2 of "beaver pond" habitat to lower Fish Creek, a 15-fold increase over natural levels. The volume increase of 3,600 m^3 was even greater--a 29 fold increase. Based on observations of wild coho abundance in 1982 and 1983, the pond might increase smolt output from Fish creek by 25 to 80 percent.

6. The Christmas ice and wind storm accounted for 62 percent of the large woody debris in the survey reaches of Fish Creek, or 80,600 bd ft. The volume in the stream represents less than one half of one percent of the total 1983 blowdown in the Fish Creek watershed. We recommend leaving this small addition and incorporating the downed trees into our fish habitat study.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Carle, F. L., and M. R. Strub. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

Korn, Lawrence, Larry H. Hreha, Roland G. Montagne, William G. Mullarkey, and Emery J. Wagner. 1967. The effect of small impoundments on the behavior of juvenile anadromous salmonids. Fish Commission of Oregon, Research Division, Portland. 91 pp.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Am. Geophys. Union Trans. (EOS) 38:913-920.

Appendix I

Temperature Data

Five Ryan Thermographs, installed and maintained by the Estacada Ranger District, are being used to collect baseline water temperature data within the Fish Creek Basin. Four thermographs are located along the lower 17 km of Fish Creek, and one is in lower Wash Creek (Fig. 34). Data was collected at one site near the mouth of Fish Creek in 1980 (Table 19) and at all five sites since then. Data collected in 1981 are presented in Table 20. The period of data collection is restricted to the summer months.

Detailed analysis of the data has not been completed but overall observations indicate that water temperatures in the summer of 1981 were favorable at all sites for production of all species of salmonids. The maximum temperature in 1981 (19°C) observed occurred on July 29, near the mouth of Fish Creek, but this.maximum was of short duration and is well within the tolerance limits of salmonids.

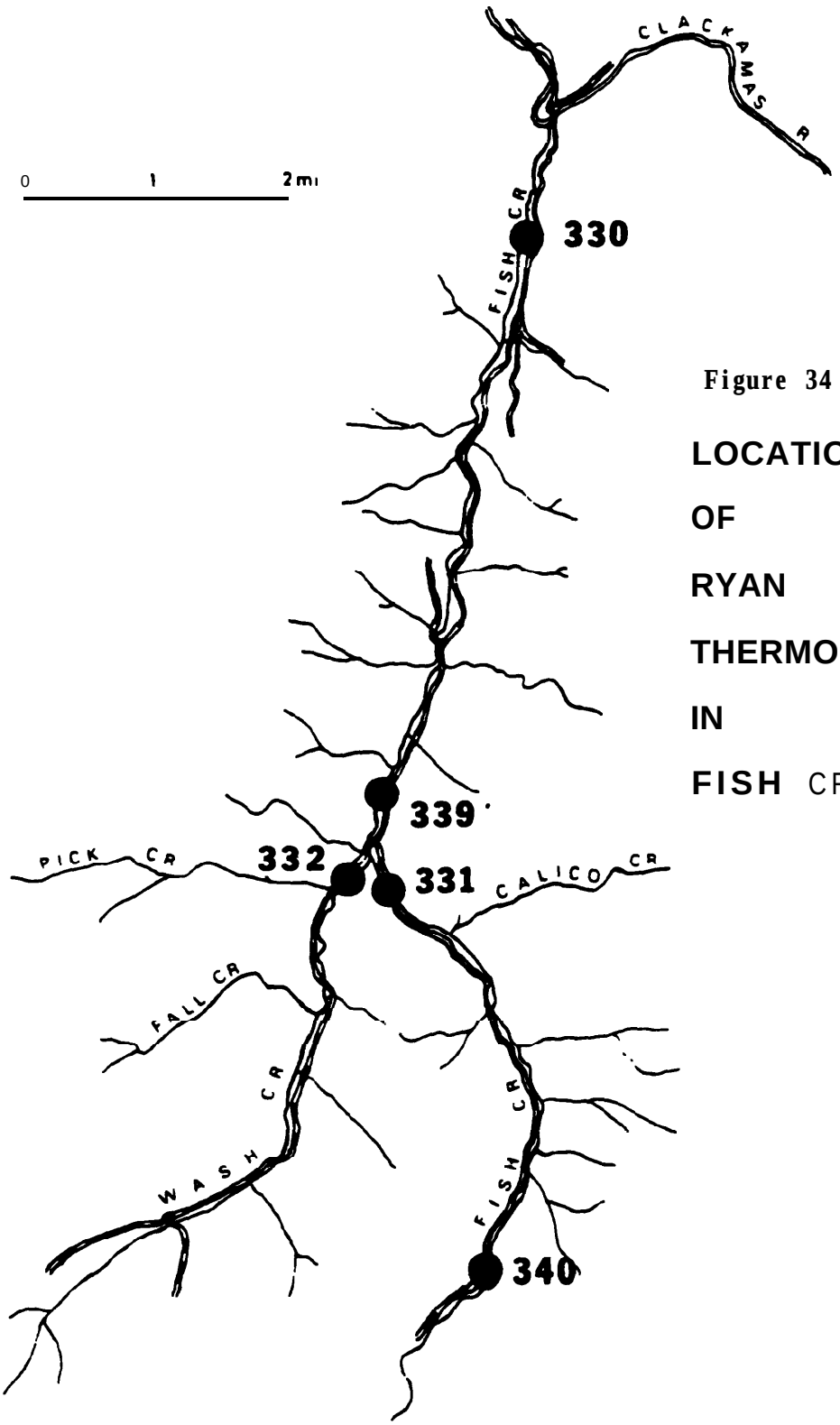

Figure 34

LOCATIONS OF RYAN THERMOGRAPHS IN FISH CREEK

Table 19. --Temperature data for September and October 1980 near the mouth of Fish Creek.

Date	SERIAL	SITES																								
YYMDD	DAY	330					HI	LO	Au	D	DDAY	HI	LO	AV	D	DDAY	HI	LO	AT	R	dta
		HI	LO	AV	D	DDAY															
80 9 2	29406	24	21	22	3	22															
80 9 4	29408	24	20	22	4	44															
80 9 6	29410	24	19	22	5	66															
80 9 8	29412	23	20	22	3	88															
80 910	29414	21	17	19	4	107															
80 912	29416	20	17	19	3	126															
80 914	29418	23	19	21	4	147															
80 916	29420	22	19	20	3	167															
80 918	29422	21	18	19	3	186															
80 920	29424	18	15	16	3	202															
80 922	29426	18	16	16	2	218															
80 924	29428	15	14	15	1	233															
80 926	29430	14	13	14	1	247															
80 928	29432	14	13	13	1	260															
80 930	29434	15	13	14	2	274															
8010 2	29436	14	13	14	1	288															
8010 4	29438	15	13	14	2	302															
8010 6	29440	14	13	14	1	316															
8010 8	29442	15	13	14	2	330															
801010	29444	14	13	13	1	343															
801012	29446	13	12	13	1	356															
801014	29448	13	13	13	0	369															
801016	29450	15	13	14	2	383															
801018	29452	16	13	14	3	397															

Table 20. -Temperature data for 5 sites in the Fish Creek Basin for the period July through September 1981.

DATE YYMMDD	SERIAL DAY	SITES																								
		332, Lower Wash					331, Fish above Wash					339, Fish below Wash					340, Fish, mile 10.5					330, Mouth Fish Creek				
		HI	LO	AV	D	DDAY	HI	LO	AV	D	DDAY	HI	LO	AV	D	CDAY	HI	LO	AV	D	DDAY	HI	LO	AV	D	DDAY
81 630	29707	12	11	12	1	12	12	10	11	2	11	12	10	11	2	11	9	9	9	0	9	13	11	12	2	12
81 7 1	29708	14	10	12	4	24	12	10	11	2	22	13	9	11	4	22	9	9	9	1	18	15	11	13	4	25
81 7 2	29709	15	10	12	5	36	13	10	12	3	34	13	9	11	4	33	10	8	9	2	27	17	11	14	6	39
81 7 3	29710	16	10	13	6	49	14	11	12	1	46	15	10	12	5	45	11	9	10	2	37	17	12	15	5	54
81 7 4	29711	15	11	13	4	62	14	11	12	1	58	15	11	13	4	58	11	9	10	2	47	17	13	15	4	69
81 7 5	29712	14	12	13	2	75	13	12	12	1	70	14	12	13	2	71	11	10	11	1	58	16	14	15	2	84
81 7 6	29713	12	9	10	3	85	12	10	11	2	81	12	10	11	2	82	10	8	9	2	67	14	11	13	3	97
81 7 7	29714	11	8	9	3	94	11	9	10	2	91	11	9	10	2	92	9	7	8	1	75	13	10	11	3	108
81 7 8	29715	13	7	10	6	104	12	9	10	3	101	13	8	10	5	102	9	7	8	2	83	15	9	12	6	120
81 7 9	29716	10	9	9	1	113	11	10	10	1	111	11	10	10	1	112	9	8	8	1	91	13	11	12	2	132
81 710	29717	10	8	9	2	122	10	10	10	0	121	10	9	10	1	122	9	8	8	0	99	12	11	11	1	143
81 711	29718	10	7	9	3	131	11	9	10	2	131	11	8	10	3	132	8	7	8	1	107	14	10	12	4	155
81 712	29719	10	7	9	3	140	10	9	10	1	141	11	9	10	2	142	9	7	8	2	115	13	10	12	3	167
81 713	29720	10	8	9	2	149	10	10	10	0	151	11	9	10	2	152	9	8	8	1	123	13	11	12	2	179
81 714	29721	13	8	10	5	159	12	9	10	3	161	13	9	11	4	163	9	8	8	1	131	16	10	13	6	192
81 715	29722	15	9	11	6	170	13	9	11	4	172	10	9	10	1	173	11	9	10	2	141	17	11	14	6	206
81 721	29728	16	11	13	5	183	13	11	12	2	184	16	13	14	3	187	11	10	11	1	152	17	14	15	3	221
81 722	29729	16	11	13	5	196	13	11	12	2	196	15	12	13	3	200	11	10	11	1	163	18	13	15	5	236
81 728	29735	17	13	15	4	211	15	13	14	2	210	16	13	14	3	214	12	11	12	1	175	19	15	17	4	253
81 729	29736	13	12	13	1	224	13	12	12	1	222	14	12	13	2	227	11	10	11	1	186	16	15	15	1	268
81 730	29737	15	11	13	4	237	13	11	12	2	234	15	12	13	3	240	11	10	10	1	196	18	14	16	4	284
81 731	29738	15	10	12	5	249	13	10	12	3	246	15	11	13	4	253	11	10	11	1	207	18	13	15	5	299
81 8 1	29739	15	10	12	5	261	13	11	12	2	258	15	11	13	4	266	11	10	10	1	217	18	13	15	5	314
81 8 2	29740	12	11	12	1	273	13	11	12	2	270	13	12	12	1	278	11	10	10	1	227	15	14	15	1	329
81 8 3	29741	12	10	11	2	284	12	11	11	1	281	12	11	12	1	290	10	10	10	0	237	15	13	14	2	343
81 818	29756	17	13	15	4	299	14	12	13	2	294	16	15	16	1	306	13	13	13	0	250	16	15	15	1	358
81 824	29762	15	13	14	2	313	14	12	13	2	307	15	13	14	2	320	12	12	12	0	262	17	14	16	3	374
81 825	29763	15	13	14	2	327	13	11	12	2	319	15	12	13	3	333	12	12	12	0	274	15	13	14	2	388
81 826	29764	14	11	12	3	339	12	10	11	2	330	14	11	12	3	345	12	11	11	1	285	16	11	13	5	401
81 827	29765	13	10	12	3	351	12	10	11	2	341	14	11	12	3	357	11	11	11	0	296	15	11	13	4	414
81 828	29766	13	9	11	4	362	12	9	11	3	352	13	10	12	3	369	11	10	11	1	307	13	12	13	1	427
81 829	29767	12	10	11	2	373	12	10	11	2	363	13	11	12	2	381	11	11	11	0	318	15	12	14	3	441
81 830	29768	13	11	12	2	385	12	11	11	1	374	14	12	13	2	394	11	11	11	0	329	15	12	14	3	455
81 831	29769	13	10	12	3	397	12	10	11	2	385	14	11	13	3	407	11	11	11	0	340	15	13	14	2	469
81 9 2	29771	14	10	12	4	409	13	11	12	2	397	14	11	12	3	419	11	11	11	0	351	15	13	14	2	483
81 9 3	29772	13	11	12	2	421	13	11	12	2	409	14	11	12	3	431	11	10	11	1	362	15	12	14	3	497
81 9 4	29773	13	11	12	2	433	13	11	12	2	421	13	12	12	1	443	11	11	11	0	373	15	13	14	2	511
81 9 5	29774	13	10	12	3	445	13	11	12	2	433	14	11	12	3	455	11	10	11	1	384	15	12	14	3	525
81 9 6	29775	14	11	12	3	457	13	11	12	2	445	15	11	13	4	468	11	10	11	1	395	15	12	14	3	539
81 9 7	29776	15	11	13	4	470	14	11	12	3	457	15	12	13	3	481	11	11	11	0	406	17	13	15	4	554
81 9 8	29777	15	12	13	3	483	13	11	12	2	469	15	12	13	3	494	12	11	11	1	417	16	13	15	3	569
81 9 9	29778	14	11	13	3	496	13	11	12	2	481	14	12	13	2	507	11	11	11	0	428	15	13	14	2	583
81 910	29779	14	12	13	2	509	13	12	13	1	494	15	13	14	2	521	12	11	11	1	439	17	14	15	3	598
81 911	29780	13	11	12	2	521	13	11	12	2	506	14	11	13	3	534	11	11	11	0	450	15	13	14	2	612
81 912	29781	13	10	12	3	533	12	10	11	2	517	14	11	12	3	546	11	11	11	0	461	15	12	14	3	626
81 913	29782	13	11	12	2	545	12	11	11	1	528	14	11	12	3	558	11	11	11	0	472	15	12	14	3	640
81 914	29783	12	10	11	2	556	12	9	11	3	539	13	10	12	3	570	11	10	10	1	482	14	11	13	3	653
81 915	29784	13	11	12	2	568	13	11	12	2	551	14	11	13	3	583	11	10	10	1	492	15	12	14	3	667
81 916	29785	14	11	13	3	581	13	11	12	2	563	15	13	14	2	597	12	11	12	1	504	16	13	15	3	682
81 917	29786	14	12	13	2	594	13	11	12	2	575	15	12	14	3	611	12	11	12	1	516	16	13	15	3	697
81 918	29787	14	12	13	2	607	13	12	12	1	587	13	12	13	1	624	11	11	11	0	527	15	13	15	2	712
81 923	29792	10	9	10	1	617	11	9	10	2	597	11	10	11	1	635	9	9	9	0	536	12	9	10	3	722
81 924	29793	9	8	8	1	625	10	9	10	1	607	10	9	10	1	645	8	8	8	0	544	11	9	10	2	732
81 925	29794	9	8	8	1	633	10	9	10	1	617	10	9	10	1	655	8	8	8	0	552	11	10	10	1	742
81 926	29795	9	8	9	1	642	10	9	10	1	627	10	9	10	1	665	8	8	8	0	560	10	10	10	0	752
81 927	29796	10	9	9	1	651	11	10	11	1	638	11	10	10	1	675	9	8	8	1	568	11	10	11	1	763
81 928	29797	9	9	9	0	660	11	10	11	1	649	11	10	10	1	685	8	8	8	0	576	11	10	11	1	774

Appendix II

Observed redds and adult salmonids during surveys of the Fish Creek System, 1981-1984.

Table 21.--Redd count data by area, Fish Creek 1981-82.

Date	Section	Redds	Adults
14 Oct. 81	Mouth to first bridge	27	30
29-22 Oct. 81	Off-channel reach	6	5
	Suspender reach	0	2
	Rock berm reach	0	2
	Lower Fish Creek	0	2
	Middle Fish Creek	0	2
9-11 Nov. 81	Suspender reach	0	1
	Lower fish Creek	4	1
	Wash Creek reach	0	5
	Upper Wash Creek	0	3
18 Nov. 81	Beaver reach	2	0
	Off-channel reach	1	0
	'Suspender reach	2	1
	Rock berm reach	1	1
	Wash Creek reach	3	1
10 Dec. 81	Rock berm reach	0	0
20 Jan. 82	All reaches	0	0
9 Feb. 82	All reaches	0	0
24 Mar. 82	Beaver reach	1	1
	Off-channel reach	2	0
	Suspender reach	1	0
	Rock berm reach	0	0
	Wash Creek reach	0	0
18 May 82	Beaver reach	2	0
	Off-channel reach	0	0
	Suspender reach	3	0
	Rock berm reach	6	0
	Wash Creek reach	8	0

Table 22.--Redd count data by area, Fish Creek 1982-83.

Date	Section	Redds	Adults
21 Sep. 82	Beaver reach	8	11
	Off-channel reach	0	0
	Suspender reach	0	0
	Rock berm reach	18	0
	Lower Fish Creek	2	4
	Wash Creek	7	0
	Upper Wash Creek	0	0
29 Sep. 82	Beaver reach	13	8
	Off-channel reach	1	0
	Lower Fish Creek	6	4
19 Oct. 82	Beaver reach	29	10
	Off-channel reach	8	2
	Suspender reach	12	5
	Lower Fish Creek	21	5
	Middle Fish Creek	2	0
	Wash Creek reach	6	0
25 Jan. 83	Beaver reach	0	0
	Off-channel reach	0	0
	Suspender reach	0	0
	Lower Fish Creek	0	0
	Middle Fish Creek	0	0
	Wash Creek reach	0	0
	Rock berms	0	1
13 May 83	Beaver reach	5	0
24 May 83	Beaver reach	1	0
	Middle Fish Creek	3	0
	Suspender reach	1	0
	Rock berns	4	0
	Wash Creek	1	0

Table 23.--Redd count data by area, Fish Creek 1983-84.

Date	Section	Redds	Adults
28-29 Sep. 83	Beaver reach	3	7
	Beaver to offchannel reach	7	20
	Start of Suspender reach	1	1
	Lower Fish Creek	0	0
	Wash Creek reach	0	0
15 Nov. 83	Middle Bridge to Trib Forks	0	0
29 Nov. 83	Beaver reach (directly below pond outlet)	3	4
20 Dec. 83	Beaver reach	2	0
	Tributary opposite beaver pond	1	0
	Old Beaver offchannel area-far bank	3	0
11 Jan. 84	Beaver pond (directly below outlet)	1	0

Table 3.--Counts of upstream migrant coho at North Fork Dam, Clackamas River, 1959-60 to 1968-69 (total includes jacks).

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1959-60	0	0	25	609	394	126	176	0	1,330
1960-61	0	0	433	1,227	155	278	91	1	2,185
1961-62	0	1	95	699	855	226	312	1	2,189
1962-63	0	0	234	1,612	933	123	217	1	3,119
1963-64	0	1	189	1,032	246	337	74	0	1,879
1964-65	0	25	234	749	1,043	228	197	0	2,476
1965-66	0	40	563	2,137	423	718	58	0	3,939
1966-67	0	1	174	308	245	39	11	0	778
1967-68	1	0	441	274	421	271	88	2	1,498
1968-69	0	91	979	2,163	1,047	192	216	8	4,696
Average	0.1	15.9	336.7	1,006.1	576.2	231.0	144.0	1.2	2,409